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ABSTRACT

This proceedings is comprised of the edited papers presented at the 21st meeting of the Western Australian Science Education Association (WASEA). The 26 papers included here relate to many different topics such as proportional reasoning, the state of primary science in Western Australia, faculty culture, concept formation in elementary science, use of technology, employing a constructivist philosophy in curriculum and instruction, understanding the atomic model, use of multimedia materials, understanding chemical equations, differentiating heat and temperature, managing science equipment, prior knowledge, social justice in school science, portfolio assessment, gender-inclusive technology, culturally sensitive learning environments, kinematics graphs, and delivery of an inclusive science curriculum. (DDR)

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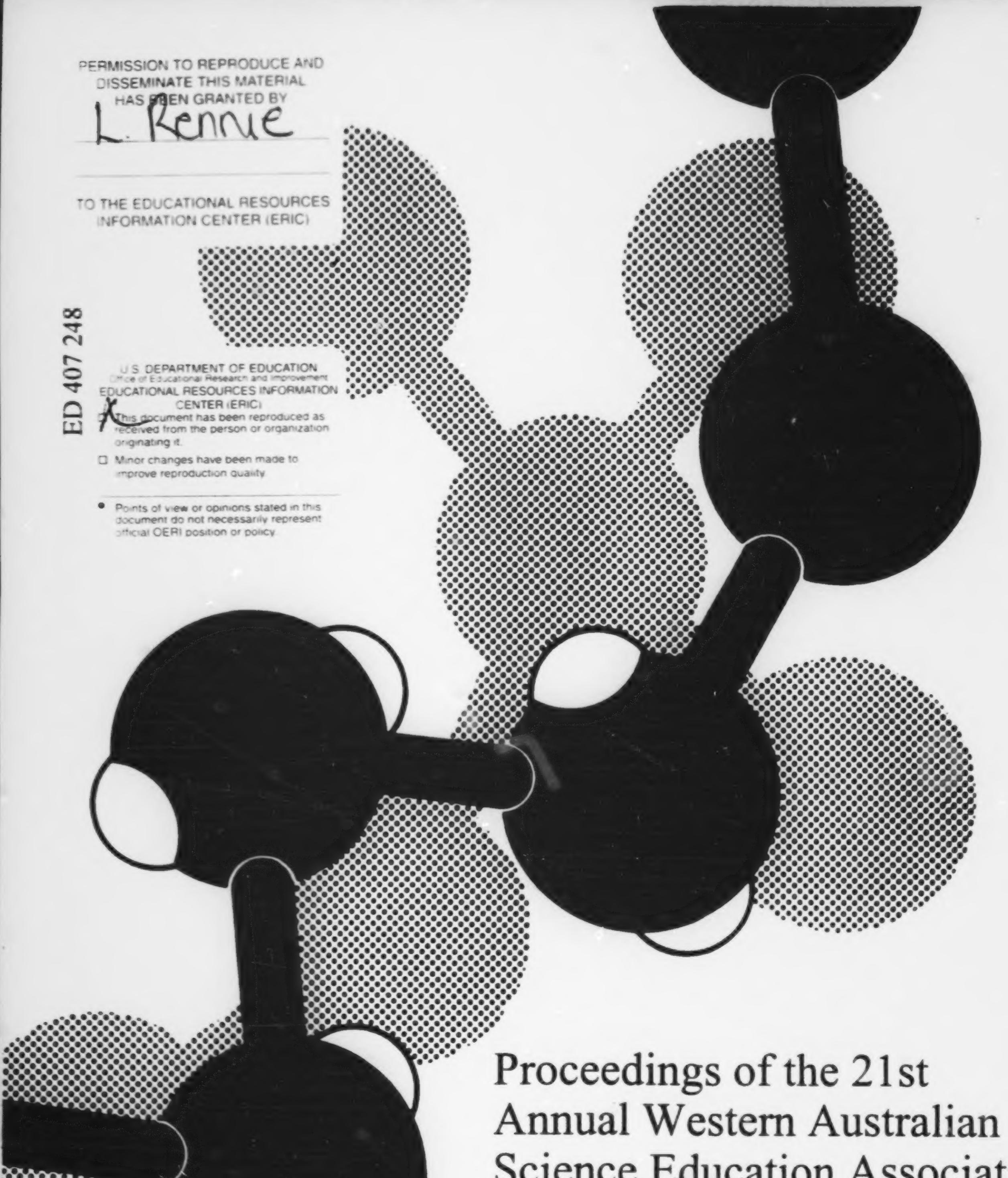

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Preface

The Western Australian Science Education Association (WASEA) is an informal group of science educators that meets annually for a conference at one of the Perth universities. The conference is organised by a committee of representatives from the universities and has contributed greatly to collegiality amongst the community of science educators in Perth.

The first meeting of WASEA was held at the Churchlands College of Advanced Education in 1975 and has been held each year except in 1979 and 1991 when the WASEA meeting was incorporated into the meeting of the Australian (now Australasian) Science Education Research Association.

These Proceedings comprise edited papers from the 21st meeting held in 1996. This collection of papers has been made available internationally through the Educational Resource Information Centre (ERIC). Enjoy them.

Mark W Hackling
Editor

Proceedings of the 21st Annual Conference of the Western Australian Science Education Association

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Students' Understanding of Upper and Lower Fixed Points of a Thermometer and it's Influence on their Proportional Reasoning

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Science and Mathematics Education Centre
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Abstract

This paper delineates students' understanding and interpretations of the upper and lower fixed points of a thermometer which emerged during an investigation of their use of proportional reasoning. The influence of these interpretations on their proportional reasoning ability are also discussed. A qualitative and interpretive case study was carried out with six students from a co-educational urban high school for five months. Research techniques such as dialectic discourses, interviews, video and audio recordings were employed to generate, analyse and interpret data. The findings indicated that in practical terms, students interpreted the upper and lower fixed points of a thermometer to mean the upper and lower limits of any thermometer scale. This made it difficult for the students to solve thermometry tasks using proportional reasoning. In this paper the sources of students' interpretations are explored and the implications for teaching high school physics are discussed.

Introduction

This paper explores one of the outcomes of a study which investigated aspects of students' use of proportional reasoning in physics. The study adopted an interpretivist framework to understand the meanings, actions, interpretations and constructions of some high school students as they solved physics tasks requiring proportional reasoning. The investigation focused on the various social and psychological aspects of students' use of proportional reasoning within their immediate high school physics classroom contexts. This paper delineates one of the socially and experientially based students' joint constructions which evolved during the study. That is the association between students' understanding of the concept of the upper and lower fixed points of a thermometer and their proportional reasoning.

Many of the concepts traditionally taught in secondary school physics are highly abstract and hence require the students to function at the level of formal operations to attain comprehension (Herron, 1978; Shayer & Adey, 1982; Williams & Cavallo, 1995). Several studies have shown that one of the formal reasoning patterns important to students' academic success in high-school science courses, especially physics, is proportional reasoning (Akatugba, 1995; Fleener, 1993; Guckin & Morrison, 1991; Heller, Ahlgren, Post, Behr, & Lesh, 1989; Lamon, 1993; Lawson, Karplus, & Adi, 1978; Whitmer, 1987). However, high school students have difficulty using proportional reasoning (Hart, 1978; Heller *et al,* 1989; Lamon, 1993). Many high school students have difficulty understanding physics concepts and often have misconceptions (Williams & Cavallo, 1995). A misconception is a preconception, an alternate conception, or an understanding that differs from the understandings held by experts in the field (Hestenes, Wells, & Swackhamer, 1992).

Several studies have shown that the problems students have in learning science concepts are as a result of their difficulty with proportional reasoning in general and in transferring it to the unfamiliar contexts in science (Guckin & Morrison, 1991; Heller *et al,* 1989; Linn, 1982; Whitmer, 1987). This suggests that understanding formal concepts may be difficult among students who have not developed proportional reasoning ability. When students attempt to learn formal concepts, a mismatch occurs between their proportional reasoning ability and that needed to understand the concept (Williams & Cavallo, 1995). There seems to be an association between students' proportional reasoning ability and their understanding of formal concepts. Most previous works in this area have focused on how students' difficulty with proportional reasoning makes it difficult for them to understand most physics concepts. However it is also clear that, inadequate understanding (or misconception) of physics concepts makes it difficult for students to use proportional reasoning. Hence students' understanding and interpretation of physics concepts also influence their use of proportional reasoning.

The concept of the 'upper and lower fixed points' of a thermometer is an important aspect of the high school physics curriculum. Most physics textbooks define the 'upper fixed point' as the temperature of steam from pure water boiling at normal atmospheric pressure (100°C) and the 'lower fixed point' as the temperature of the melting-point of ice (0°C). An appropriate understanding of this concept is necessary for successful and meaningful solving of thermometry tasks in physics using proportional reasoning. Explaining the association between students' understanding or interpretations of this concept and their use of proportional reasoning is one of the purposes of this paper. The study investigated aspects of students' use of proportional reasoning in physics problem solving during which students' misconception of the concept of the 'upper and lower fixed points' of a thermometer emerged. This paper is aimed at delineating the misconceptions students had on the two fixed points of a thermometer, how these misconceptions influenced students' use of proportional reasoning, and the reasons for their understandings.

Research Design

A constructivist and interpretive (Bogdan & Biklen, 1992; Guba & Lincoln, 1987; Maykut & Morehouse, 1994; Meriam, 1988) case study was carried out with six grade 12 physics students from a co-educational senior secondary school in Nigeria. The purpose of the study was to understand the constructions that individual students and groups of students form in order to make sense of their difficulty with proportional reasoning within their social and cultural contexts. A hermeneutic dialectic process (Schwandt, 1994; Grundy, 1993; Guba & Lincoln, 1989) and an emergent approach was adopted for data collection and analyses through out the investigation. The hermeneutic dialectic process was used to engage each learner with some physics tasks and open-ended interviews were employed to elicit learners' initial emic constructions. Each participant was given the opportunity to compare and contrast their own emic constructions with some of the constructions which emerged from other participants in the hermeneutic dialectic circle in order to obtain their joint constructions on the issues which emerged. This design also afforded learners the opportunity to negotiate the differences in their individual constructions in order to arrive at a consensus.

Research Procedure

The six students were selected serially using a maximum variation sampling method (Guba & Lincoln, 1989; Maykut & Morehouse, 1994). The students were actively engaged with various physics tasks requiring proportional reasoning during which multiple research techniques were employed to elicit their claims, concerns, meanings and constructions of their problems with proportional reasoning. These physics tasks were adapted and in some cases modified from some past West African School Certificate (WASC) examination questions in physics requiring proportional reasoning and some proportional reasoning tasks used by other researchers in the field which were related to the students' physics syllabus. The techniques employed included observation, dialectical discourses, structured/unstructured interviews, questionnaire, dialogue journals, field notes, proportional reasoning tasks, video and audio tapings. Students' misconceptions about the upper and lower fixed points of thermometers emerged as one of the problems influencing their use of proportional reasoning in physics problem solving. Physical thermometers, diagrams and some of the techniques mentioned above were employed to understand the nature of the problem and to elicit students' constructions about the problem.

Data Analysis

The data analysis process closely followed the data collection process and was an ongoing part of the research (Bogdan & Biklen 1992). The data and the analyses were constantly checked with individual participants. Data interpretations were based on the constructions with which each learner, group of learners and the researchers made sense of the various issues which emerged and the values and beliefs which shaped them. These interpretations were also linked to the immediate contexts within which the constructions were formed and to which they referred (Fieldman, 1995; Guba & Lincoln, 1989).

Outcomes

Students' misconception of the 'upper and lower fixed points' of a thermometer became apparent when they attempted to solve the three thermometry tasks (See Appendix 1) in the given physics tasks. It would be worthwhile to note at this point that the students had all previously studied the concepts of 'thermometers' and 'the fixed points of thermometer' in their physics lessons. None of the six students were able to solve the three tasks using proportional reasoning. They believed that there were no other ways by which they could solve the thermometry tasks. Initially students felt that their inability to solve these tasks had to do with the nature of the tasks themselves.

Student's Initial Reactions To The Tasks

After trying without success to solve the tasks, the students claimed that the information provided in the given tasks was incomplete. The students complained that the temperature units provided in each of the three tasks were all the same (eg. mm or degrees) and could not understand why they were required to calculate the temperature in a different unit (degree Celsius). Students were not used to thermometers with 'mm' and ordinary 'degrees' as units. Students became confused by the tasks and their constructions are illustrated using the task below:

Task 1: A thermometer has its stem marked in millimetres instead of degree Celsius. The lower fixed point is 30 mm and the upper fixed point is 180 mm. Calculate the temperature in degree Celsius when the thermometer reads 45 mm.

Commenting on why they could not solve the thermometry tasks such as the one above, some students said:

Student A: What confused me was the mm. I've never seen a thermometer using mm. ....The thermometer was marked in mm and all of a sudden they just said find that out in degree Celsius. And I didn't know how to do that.

Student B: I don't see any relationship between the °C and the mm. When they give questions, like density now, it means mass/volume. But looking at this *mm* with *degree* I can't find any relationship and any formula that I know and I could not do it either.

Students believed that the tasks were incomplete. Their comments showed that they did not have an adequate understanding of the task and the task requirement. In order to complete the tasks they needed some prior basic knowledge of the 'upper and lower fixed points' of thermometers.

Lack of Awareness of Task Requirements

Further experiences, discussions and reflections on the three thermometry tasks revealed that the tasks relied on the assumption that students had a prior understanding of the concepts of the upper and lower fixed points. Students were also required to have a knowledge of the values of the upper and lower fixed points in degree Celsius and to link these knowledge with the information provided. However, they did not realise this until they were asked to reflect on and discuss the physics concepts , the tasks content and the task requirement:

Researcher: Why were you not able to understand on your own that you were going to need the equivalent of the values you were given in degree Celsius in order to solve the problem?

Student : When I saw it I thought it was like converting Centigrade to Fahrenheit or something like that. I didn't sense it would need requiring that I bring in the values of the upper and lower fixed points in degree Celsius.

Researcher: Why couldn't you relate that on your own?

Student : I thought perhaps they left out all the information about the question on the temperature in degree Celsius.

The students later realised that the tasks were also testing their knowledge of the values of the upper and lower fixed points in degree Celsius, and their ability to convert from any scale to the Celsius scale. However, all six students involved in the study got stuck when they tried to find the temperature values in degree Celsius. It became obvious at this stage that students were not sure of the actual values of the upper and lower fixed points of thermometers in degree Celsius. They were not sure if the values were fixed or whether it varied with different thermometers. As a result they were not sure of the values in degree Celsius which they needed to carry out the conversion from the mm scale to the Celsius scale. Hence there appeared to be some internal conflicts and confusions within all the students and these affected their reasoning. Student B's initial attempt at solving Task 1 above is shown below:

Task 1: lower fixed pt is30mm, while the lower fixed pt in degree Celsius is 0

30mm = 0°   1mm = 0/30

45mm = x   45mm = 0/30 x 45

Like the other students, Student B tried to solve the above problem based on his past practical experience and constructions on different thermometers. He had come across different types of thermometer with different range of values and this made it difficult for him to figure out the values of the lower and upper fixed points in degree Celsius. It became evident that he did not understand the meaning of the concept 'upper and lower fixed points of a thermometer'. This influenced his workings which is shown above. Student B provided some insight into what he had done:

> When I read the lower fixed point was 30mm, like from what I have known from thermometers, the lowest degree in Celsius is 0. So I thought that if in 'mm', the lowest degree was 30, that means for the Celsius [scale] it will be 0. ... Why I was stuck here was that I was trying to use ratio and I found out that if *30mm is equal to 0°C* then *1mm will be 0/30*. ...Since my answer was infinity, anything I do will always end up as infinity and that did not look practical to me. In the sense that [a] thermometer has an end.

It was at this stage that their misunderstanding of the upper and lower fixed points of a thermometer became apparent. Hence all six students and one of the researchers (first author) later came together to understand the nature of the students misconception of the two fixed points.

Students' Interpretations of the Upper and Lower Fixed Point of Thermometers.

The activities and discourses with individual students indicated that the students were confusing the upper and the lower fixed points of a thermometer with the lowest and highest values that could be found on any thermometer scale. In order to understand students' own interpretations of the upper and the lower fixed points and enable them to reflect on their interpretations, they were all given thermometers with different range of values similar to the ones shown in Figures 1-4. Each student was asked to indicate the two fixed points on the thermometers and they all showed the lowest and highest values on their thermometers as their upper and lower fixed points. That is *0°C and 100 °C, 35°C and 43°C, -10°C and 110°C,* and *-15°C and 115°C.*

The student with the thermometer similar to the one in Figure 1 appeared to have had the correct values. However, when the same student was given another thermometer similar to that shown in Figure 2, he said the values of the upper and lower fixed points were *35°C and 43°C* respectively. This showed that the student did not understand the concept and was having a misconception like the other students, . Students were of the opinion that these two values (even though they are referred to as fixed points) varied with different thermometers. They were confusing the upper and lower fixed points with the upper and lower limits of a thermometer scale and consequently had problems solving the three tasks using proportional reasoning.

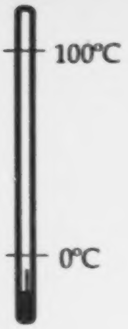

Fig.1

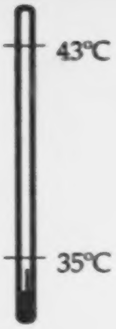

Fig. 2

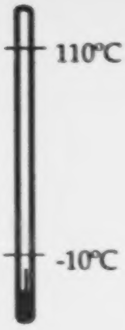

Fig. 3

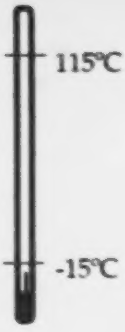

Fig. 4

When the students were asked to reflect on the meaning of the concept of the upper and lower fixed points and to explain what these meant to them, they realised the discrepancies between the values they had given and their definitions of the concept. Most of the students defined the lower fixed point as the "temperature of melting ice" and the upper fixed point as the "temperature of steam from boiling water". They gave both values as 0°C and 100°C respectively. When the students were asked if the temperatures at which ice melts and water boils are fixed or varied, they claimed the temperatures are fixed. It was at this stage that they realised their misconception and understood that the values for the upper and lower fixed points of thermometers are fixed and not the same as the lowest and highest values on the different thermometer scales.

The Influence of the Misconception on Students' Proportional Reasoning.

The students needed to know the values of the two fixed points in the Celsius scale in order to solve the problems using proportional reasoning. Since students associated the fixed points with the lowest and highest values on a thermometer scale and reasoned about these in terms of different values for different thermometers, it did not occur to them that what they needed were the values 0°C (lower fixed point) and 100°C (upper fixed point). Before they were given the different thermometers for further investigation, some of the students said the lower fixed point was 0°C while some were not too sure about this value. Further probing showed that the students were not sure because they had seen some thermometers similar to the ones in Figures 3 & 4 which ranged from -10°C to 1 00°C, -10 to -110°C, -15°C to 100°C, and -15°C to -115°C. As a result they believed that the lower fixed point could also be -10°C and -15°C. Others chose 0°C as the lower fixed point because they had only seen thermometers with scales beginning from 0°C. Hence some students associated the '30mm' in the first task with 0°C and others could not associate it with any particular value.

However, none of the students were conclusive about the value for the lower fixed point. They particularly found it difficult to comprehend the value of the upper fixed point as 100°C. They figured that the value should be varied since they had seen and heard about thermometers with values ranging between -*10°C and 220°C, 0°C and 100°C, 35°C and 43°C, etc.* Explaining why some did not have much problem with the value for the lower fixed point (0°C), they claimed that the thermometers they were used to seeing started from 0°C but had different "upper fixed points". Students needed a knowledge of both values of the upper and lower fixed points in degree Celsius as well as a good understanding of their meaning and relevance for them to be able to relate the information in the given tasks as shown in Figure 5.

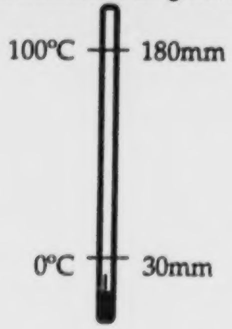

Fig. 5

A dialogue with one of the students illustrates how this misunderstanding influenced his proportional reasoning:

Researcher:	What will 30mm correspond to in degree Celsius?
Student:	That's 0°C.
Researcher:	What will 180mm correspond to in degree Celsius?
Student:	Hmm, I can't remember.
Researcher:	Why did you choose 0°C as the lower fixed point?
Student:	Hmm, from what I have known about the thermometers around, they are calibrated in 0°C, 1, 2, 3, to 100. ... they start from 0°C.
Researcher:	Apart from seeing this from the thermometers, did you know that 0°C is the lower fixed point of a thermometer in degree Celsius?
Student:	I knew in the sense that ... definitely it will start from zero. I have never seen something like -2, -2.5, or -3.5.
Researcher:	If 0°C is the lower fixed point what is the upper fixed point?
Student:	I don't think there will a definite upper fixed point. ... The thermometers I have seen are up to 45°C and some are up to 200°C. ... I have heard of [thermometers that are up to] maybe 2000°C and 5000°C.
Researcher:	So what was your problem with the question?
Student:	What confused me was that I have seen different types of thermometers. Since there are different types of thermometers, that put me in a fix in the sense that I did not know what type of thermometer they were talking about. May be the one used for measuring [the temperature of a] human body or the one used for measuring [the temperature of] a reaction.

What the students had seen, heard and read about different types of thermometers influenced their understanding of the upper and lower fixed points of a thermometer and subsequently, their ability to solve thermometry tasks using proportional reasoning.

Students' Constructions of their Misconceptions

Students' misconception was partly attributed to lack of understanding and questioning on the part of the students. They believed that if they were made to understand the meaning of the term or phrase 'upper and lower fixed points' and encouraged to ask questions during physics lessons, they would not have had such misconceptions and this would have minimised their difficulty . The students believed that if their teachers drew their attention to the knowledge that the upper and lower fixed points were *fixed* irrespective of the different types of thermometers, that would have helped them in solving the tasks. Students said their knowledge about different types of thermometers from physics and chemistry interfered and confused them during problem solving.

The students also believed that their misconception was also due to the problem of language. Students tended to associate scientific terms or phrases with their everyday understanding of similar words or terms. As a result, students lost the scientific meaning of such terms like 'the upper and lower fixed points of a thermometer' when they learned the concept Students felt that they should have been taught the linguistic meaning of the phrase 'upper and lower fixed points' during physics lessons and that the focused should not only be on the scientific aspects of the concepts in physics.

Students also associated their misconceptions with the way physics concepts especially the concept of the upper and lower fixed points are taught in the physics classroom and the way they are presented in physics textbooks. They claimed that they learned this concept in such a way that they could not appreciate its meaning and relevance. They were usually given the definitions, told the values and not made to understand why these values are fixed. The different contexts where these values could be relevant were not explored. Students claimed that no emphasis has been placed on the *fixed* nature of the values of the two fixed points. Students feared that the concept was not taught as an important aspect of physics yet it played such a vital role during problem solving. They also complained that the physics textbooks only casually mentioned such concepts or do not at all.

Implications

The outcomes of the study indicates that students misconceptions of the concept of the upper and lower fixed points of a thermometer influence their ability to solve physics thermometry problems using proportional reasoning. These misconceptions are associated with students experiences and knowledge of different thermometers, the way the concept is taught in the classroom, lack of understanding and questioning on the part of students, and the alternative everyday meanings and interpretations students assign to scientific terms that are not well explained to them.

Proportional reasoning is essential for successful solving of thermometry tasks (which appears frequently in the West African School Certificate Examinations). However an adequate understanding of the meaning and relevance of the concept of the upper and lower fixed points of a thermometer is required to enable students use proportional reasoning. But this concept is taught in the classroom and mentioned in both textbooks and physics curricula in a way that devoid it of it's meaning and relevance. Most physics curricula briefly mention the need for students to be able to *define* the upper and the lower fixed points while some totally skip it. Subsequently, most texts book provide only the definitions of the fixed points and the few which attempt to provide some explanation portrays these fixed points as the 'lower and upper values' on a thermometer. Students are not given the opportunity to use and appreciate the meaning and relevance of the fixed points. The concept is usually not treated as a main issue in the physics curricula and textbooks, and as a result it is not taught in-depth.

Another important implication of this study is that most physics students hold some confusion about the upper and lower fixed points that do not become obvious until they are faced with problem situations involving the concept. Most of the students are not even aware that they have misconceptions until they are made to reflect on the definitions, the meanings and the implications. Some students are able to state the right values of the fixed points in the Celsius scale in a particular context (which they may not really understand) and are not able to do so in different contexts. Statement of the right values does not depict an understanding of the concept of the upper and lower fixed points. Hence students' understanding and interpretations of the two fixed points need to be anticipated and accessed during instruction, learning, and problem solving in physics.

Most scientific terms students encounter in school do not exist in their everyday vocabulary. Although some scientific terms like 'upper and lower fixed points' may seem simple and straight forward and are assumed to be understood by students, they usually take on meanings that are different from those held by experts in the field. If potential students' misinterpretations of scientific words such as the 'upper and lower fixed points' are not anticipated and dealt with, students stand the risk of relating such words to their everyday understanding of 'lowest' and 'highest'. This leads to misconceptions and difficulties. Hence there is a need to devote some time to the learning and understanding of most scientific terms in order to ensure that students hold useful interpretations which are in line with those held by experts. Finally, there seem to be a need for a reconciliation of what students see everyday, what they read and what they are taught in physics classrooms so as to identify and deal with possible differences and discrepancies.

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Appendix 1

1. A thermometer has its stem marked in millimetres instead of degree Celsius. The lower fixed point is 30 mm and the upper fixed point is 180 mm. Calculate the temperature in degree Celsius when the thermometer reads 45 mm.

2. A mercury-in-glass thermometer reads -20 ° at the ice point and 100 ° at the steam point. Calculate the Celsius temperature corresponding to 70 ° on the thermometer.

3. The ice and steam points on mercury in glass thermometer are found to be 90.0 mm apart. What temperature is recorded in degree Celsius when the length of the mercury thread is 33.6 mm above the ice point mark?

The State of Primary Science in Western Australia: A Survey Review

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Introduction

Prior to 1994, there was little activity in the promotion of primary science in Western Australian government schools since the development of the *Science Syllabus K-7* (Education Department, 1983) in 1983/4. There was evidence to suggest that many teachers were not teaching science well, if at all. There was concern about "the relatively low priority and small amount of time devoted to science education in primary schools, (approximately one hour each week) and the consequent generally low level of understanding displayed by primary students" (Education Department, 1994, p.3). In 1993 the Education Department of Western Australia tested Year 3 and 7 students statewide to determine the level of achievement in science. The *Monitoring Standards in Education(MSE) Report* (Education Department, 1994) discussed the achievements of students in five areas. The four conceptual areas and one process area were drawn from a *Profile of Science for Australian Schools,* the federal Labour government's attempt at a National Curriculum. The MSE Report highlighted a particular concern about the nature of science lessons: "Year 7 students reported a generally low frequency of science activity. The most common activity reported for Years 7 and 10 students was copying notes from the blackboard and completing worksheets." (Education Department, 1994, p.7) The results of this report prompted action from the Education Department of Western Australia resulting in the Science Project.

In 1995 and 1996 the Education Department directed considerable funding to primary science through the Science Project. The Project Targets were defined as follows:

- Provide all schools with access to exemplary curriculum materials.
- Establish an effective, whole school curriculum in primary schools.
- Establish science teaching methodology that is consistent with identified best practice.
- Provide access for teachers to update their knowledge of science and its role in society.
- Establish networks of curriculum leaders to provide ongoing support for teachers beyond the life of the project.

The Project has resulted in considerable activity in classrooms, schools and school districts (Venville, Wallace & Louden, 1996). Much of the recent activity can be compared with that which took place during the period 1980-1985 when the *Science Syllabus K-7* (Education Department, 1983) was introduced and primary schools were assisted to develop whole school science programs. This earlier period of activity was described in *A Review of Primary Science in Western Australia 1980-1985* (Betjeman, 1985)—a report of a survey of schools' perceptions of the state of primary science at that time. In this report Betjeman (1985) also describes the various professional development and curriculum development initiatives of the time. The report is positive about the changes that took place in science at those times but is also realistic. "Primary science is still in the process of confirming its identity and direction in Western Australia." (Betjeman, 1985, p.42). The aim of this paper is to report on schools' perceptions of the current state of primary science in Western Australian government schools and to compare these perceptions with those reported in the earlier survey by Betjeman (1985).

Methodology

A postal questionnaire was developed to survey the state of science in Western Australian government primary schools. The survey can be described in four main sections. The first section dealt with the demographic information such as location and classification (not included in this paper). The second section was modelled as closely as possible on the Betjeman (1985) survey so that direct comparisons could be made. It consisted of seven questions requiring a yes or no response, a question on curriculum use in which respondents were asked to identify the type of science curriculum being used their school and a question about time spent on science at each year level. In the third section, respondents were asked a series of questions about awareness of current activity; participation in professional development; teaching strategies; monitoring tools and their uses; and, achievement of outcomes. The final section invited a general response and participants were invited to use an extended answer method to comment on any primary science issue. The survey was sent to 665 government schools (all schools with a primary population) addressed to the science coordinator, through the principal. Approximately 418 were returned representing a return rate of 63%.

Results

Awareness of Science Project

In this question, respondents were asked about the level of awareness among the staff of aspects of the Science Project (project leaders, project plans and project content). The responses indicate that in most schools at least one person is aware of each of these aspects of the Project (see Figure 1). Of interest is the number of respondents who were unaware of the existence of Primary Teacher Leaders (9.4%), district Project plans (13.9%) or the content of the Science Project (18.5%). These figures represent a significant number of teachers who were not aware of the Science Project. Country schools are more likely to be aware of district plans and activities than metropolitan schools.

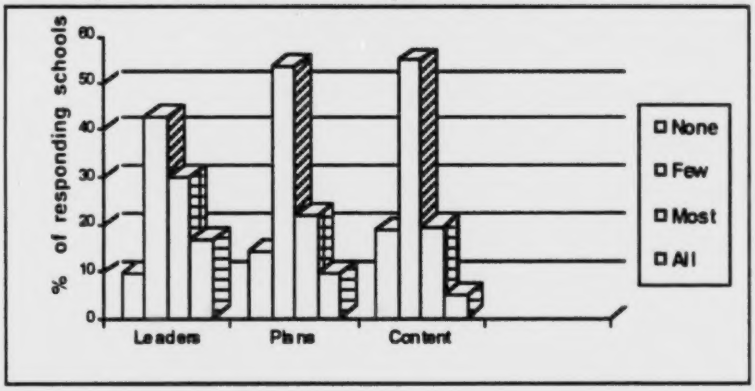

Figure 1. Awareness of the science project

Participation in Professional Development

There was a high level of participation in professional development activities associated with the Project (see Figure 2). A third (30.7%) of respondents said that their whole staff had participated in professional development in science in 1995-96. This can be closely correlated with the number of schools who reported that they were using *Primary Investigations* (30.2%). It should also be noted that only one tenth (10.1%) of respondents said that no person from their school had participated in science professional development in 1995-96. Advice was sought from central office and/or district office staff by one or more people in 77.2% of schools. Country schools were more likely to have sought advice than city schools. Many schools (66.2%) reported that one or more of their staff actively involved their classes in science events in the last year. They may have participated in any one of a number of activities e.g. Science in schools week, District Science Challenges, Science Talent Search.

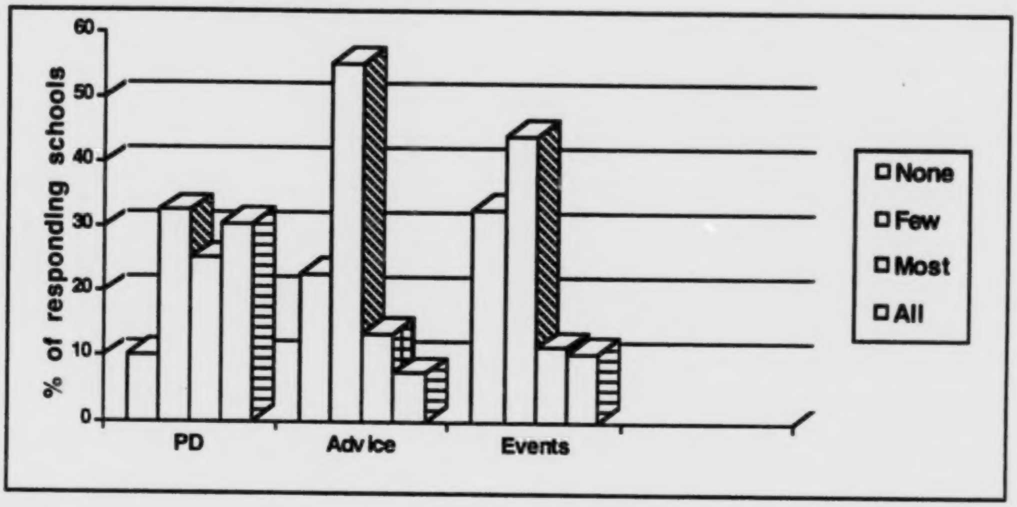

Figure 2. Participation in professional development activities

Teaching Strategies

Figure 3 shows the responses to the questions regarding teaching strategies. A whole school, coordinated program is the method of organisation of primary science supported by Education Department policy. The results show that 32.4% of respondents indicated that all staff taught science within a whole school organised program. It is interesting that by definition, all staff would be involved in a whole school science program except perhaps support staff and specialist teachers. The 29% of respondents who indicated that most of their staff taught science in a whole school program may be considering these specialist roles in their answer. This could mean that as many as 61.4% of schools may have a whole school science program. In the "science in your school" section of the survey 68.1% of respondents reported that their school was implementing a whole-staff coordinated science program.

The idea of linking science concepts and skills cross curricula is to strengthen learning that takes place in science by following it up in other areas. For example measuring temperature is a skill which may be required in science but could be used in studies of Society and Environment. Many teachers link learning areas in this way. Responses show that only 2.2% of schools say that this linking does not occur. Integrating science with other learning areas usually implies teaching in themes or around a central organiser and planning activities to develop understandings and skills across the learning areas. Results show that in many schools (53.7%) most or all teach science in this way.

Responses show that few teachers teach science in the morning. In most schools (87%) none or few teachers teach science in the morning. One response in the general comments section stated that one teacher was responsible for teaching all the science in the school and that it was timetabled in the morning for logistical reasons rather than any perceived educational benefit.

Cooperative learning strategies were used by most of the staff to teach science in 43.9% of the responding schools. Only 17.7% of schools indicated that all staff used explicit cooperative learning strategies. Compared to the 30.2% of respondents who said that all were using *Primary Investigations* at their school, this makes an interesting point. The program is based on explicit cooperative learning but apparently is not always being implemented in that way. In only 6.2% of schools were cooperative learning strategies not used in science at all.

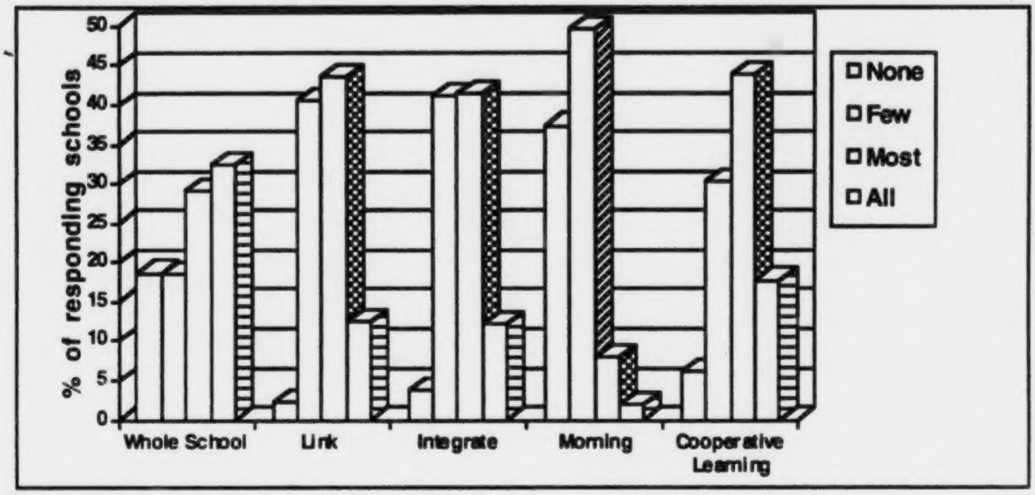

Figure 3. Teaching strategies

Time

The amount of time spent on the teaching and learning of science correlates directly with student achievement. There was a general trend that the amount of time increased directly with the age of the students. Students in Year 7 spent an average of 71 minutes on science each week as compared to Kindergarten students who averaged 49 minutes on science. There was a significant standard deviation at each year level indicating a considerable range in the amount of time spent on science.

In the general comments at the end of the survey two respondents chose to comment specifically on time. One respondent said "Whilst one hour is the average, more time is generated through extension to other areas such as language in particular." Language texts have changed significantly in the ten years since the preliminary report. New non fiction reading series often include science based texts so the comments are quite relevant. Another respondent said that it was difficult to average time spent on science over classes in a large school (Class 5) and also mentioned integration as a factor that could account for more time but it is too difficult to isolate.

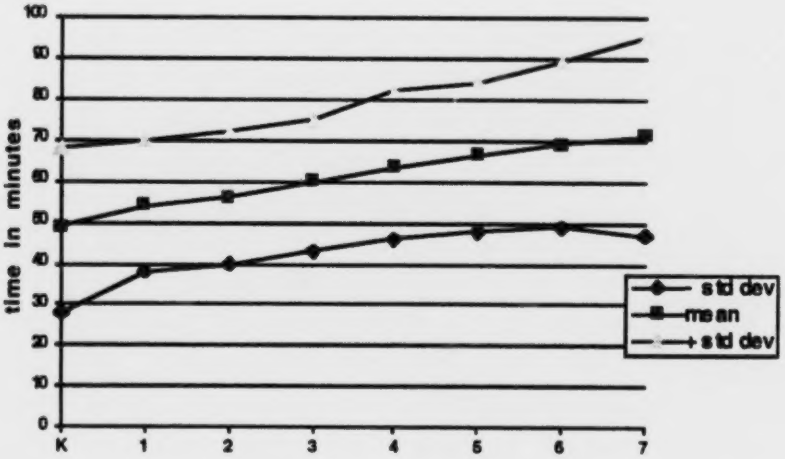

Figure 4. Time spent on science

Curriculum Use

Most schools reported using the Academy of Science program *Primary Investigations*. A little under one third (30.2%) of schools who responded said they were using *Primary Investigations* solely and a further 45.1% said they were using *Primary Investigations* and other science curriculum materials. Teacher selected topic, themes and activities accounted for 16.1% of schools and few schools (6.0%) were using a coordinated approach other than *Primary Investigations*. Of the few schools (1.7%) who indicated they used "other" curriculum materials, a wide range of curriculum materials were identified e.g. *Rigby Alive, Queensland Syllabus and Distance Education materials*.

Monitoring Tools and Outcomes

Monitoring student progress has become an increasingly important in Western Australian government schools. Monitoring in science presents difficulties in the collection of data on student skills and understandings. Data collected at a school level becomes part of the school's Managing Information System (MIS). Question 23 was encoded as yes/no for each of the choices offered and so respondents could choose more than one alternative. Table 3 shows the monitoring tools used in schools and their perceived usefulness. Teacher assessment was by far the most common method of monitoring (90.4%). Teacher assessment can range from observation and checklist to teacher made tests so this figure indicates that the responsibility for the monitoring information is made at a classroom level but does not suggest the strategies used.

Tests are used by 60.9% of schools, either *Monitoring Standards in Education* or other types of tests to monitor student progress. A further 3% said they used the *University of New South Wales* test when they responded to the alternate choice on the survey. Many schools (42.4%) indicated that monitoring information came from teachers' reports (teacher judgments). The alternatives provided did not include *Student Outcome*

Statements as such, and of the 14.4% who chose to identify another alternative, 28% indicated that they used Student Outcome Statements as a monitoring tool.

Table 4

Monitoring tools and their usefulness in guiding curriculum and pedagogical change and in making claims about student achievement of outcomes

		Curriculum and pedagogical change	Student achievement of outcomes
Monitoring tool	**% used**	**Question 24**	**Question 25**
teacher assessment	90.4	2.14	2.2
MSE tests	39.8	2.43	2.52
other tests	21.1	2.5	2.56
MIS data from teacher reports	42.4	2.36	2.46
other	14.4	2.48	2.66

Note: usefulness was represented on a four point scale where: 1 = not useful, 2 = moderately useful, 3 = useful, 4 = very useful

Schools were asked to indicate how useful they found the monitoring tools they used (see Table 3). The information collected was found to be moderately useful in guiding change in most schools. It is interesting to note that 17.3% of schools indicated that the information collected through the various monitoring methods was not useful in guiding curriculum or pedagogical change in their school. The information collected through monitoring processes was found to be moderate to useful in making claims about student outcomes. Only 7% of schools found this information to be very useful while 16.1% suggested that the information collected was not useful in making claims about student outcomes.

Improvement

Most respondents (68.5%) felt that there had been improvement in science teaching and learning in their school compared to pre 1995. Of these 28.5% reported that there had been significant improvement. When given opportunity for general comment a few respondents (5) commented on the difficulty in locating monitoring information pre 1996. These schools are in rural and remote locations where transience of staff poses difficulties for the continuity of monitoring strategies and information. They felt unable to comment on the state of science in the school pre 1996 and could therefore not identify whether or not it had improved.

General Comments

The general comments section was available for extended response and 227 schools chose to add further comments in this section. The largest group of responses (31%) discussed the school planning process. Of these, most indicated that they had a well developed school planning process and most mentioned that science had been given priority status in 1995 or 1996. Others reported the difficulties and frustrations in implementing a whole school program.

> "Our school reviewed science in '95 and decided the area needed attention. Science was included in the '96 school development plan as a focus area."

Primary Investigations was discussed by 22% of schools in the general response section. Most of the comments (36) were very positive and many suggested that the structure of the program assisted school organisation of science.

> PI - whole school - has made a tremendous difference to teaching science. It has given us some direction; hands on approach is interesting. There are a few gaps in the program but teachers are supplementing the program with others.

Some schools (14) reported difficulties in implementing the program and mentioned particular problems such as catering for composite classes and the initial costs of establishing materials and purchasing the books. Other issues discussed included professional development, the role of science specialists and science in education support centres.

Comparing the Studies

This section of the paper compares the findings from the Betjeman (1985) survey with the findings from the 1996 survey. In 1985 there were approximately 568 government schools with primary students. The survey was sent to every second school in every region of Western Australia, 87% were returned representing a sample size of 247. This survey was distributed in November 1994. The survey of science in 1996 was sent to 665 government schools and 418 (63%) were returned. This survey was distributed in July 1996.

Results

The section "science in your school" was retained in the 1996 survey as closely as possible to the original questions and format so that direct comparisons could be made between the surveys. Questions 3 - 11 of the 1996 Survey of Primary Science can be compared directly with the 1985 review (see Table 5)

Table 5

Science in your school

	% responding 'yes' to the question	
Question	**1985**	**1996**
3. grant/support	50.4	53.5
4. advisor/support	61	72.2
5. coordinator	60.6	88.2
6. policy	66	43.2
7. whole staff program	47.6	68.1
8. science equipment	96.9	94.2
9. equipment organisation	60.6	81.3

Grants

Provision of a grant is compared directly with support from the Science Project. The results are very similar and it can be seen that approximately half the schools that responded benefited from grants in 1985 or support in 1996. In 1985, grants were awarded to schools who developed a written science policy and showed commitment to the development of science within their school. The grant was used for resource purchase and curriculum materials. In 1995, the Science Project did not provide schools with direct funding for the purpose of purchasing resources. Therefore no schools received grants in the period of 1995 and 1996. However many schools received support in the form of funding provided for professional development.

Advisor/ support

In question 4, the comparison of a visit by an advisor (61%) in the 1985 study is compared to district office and central office support (72.2%) in 1996. In 1980-85 there were regional advisors in each metropolitan region and a central advisor. In 1995-96 there were School Development Officer's (SDO) in district offices of the clustered districts (regions) and a central project officer. Note that the 1995/96 district office staff were not funded by the central office project. The visit by an SDO would be equivalent to the visit by an advisory teacher. It is worth noting the similarities in these figures although there seems to be more activity in this area in 1995-96.

Science Coordinators

There has been a marked increase (27.6%) in the number of schools with school coordinators in science. There are a few reasons that may account for this. Betjeman (1985) reported that "science coordinators have been responsible for the rapid improvement in primary science since 1980." Much of the focus of the Science Project in 1995/96 has been on the development of district leaders and networks of school based coordinators. During 1995, leaders were identified who in turn identified coordinators in schools. If science coordinators are important to the improvement of science within schools then the increase is a very positive one for primary science.

Science Policy

A science policy is a clear indication of the way in which schools are addressing science education. A fall of 22.8% in the number of schools who have a written science policy may be accounted for in several ways. The advent of school development planning seems to have overtaken subject policy development in many schools and it is possible that schools do not have a written subject policy as such. The requirement of schools to have commenced a science plan in 1980-85 in order to receive grants may have caused schools to review their policy documentation. (Betjeman, 1985, p.26)

Whole staff program

In both the 1985 and 1996 projects there were attempts made to involve the whole staff in primary schools. In 1985 it was thought that "if an appropriate organisation can be embedded in the school's operation then it is more likely to have longevity despite staff transfers." (Betjeman, 1985, p.34). So the aim was to work with whole school staffs through a coordinator. The increase of 20.5% in the number of schools with whole school programs is significant as it means that decisions are made at a school level about program implementation and they are therefore more likely to have a longer life.

Science Equipment

There seems to be little difference in the number of schools that have equipment accessible to staff. In 1985, 96.9% of respondents reported that they had science equipment accessible to all staff, compared to 94.2% in 1996.

Equipment Organisation

The comparison between the 1985 question "Does your school use resource topic kits, in trays or boxes, as a way of organising science?" (60.6%) and the 1996 question "Is the science equipment in your school organised effectively?" (81.3%) is tenuous. The 1985 question was directly related to the methodology of the time and the 1996 question was an attempt to include other organisational methods. It was assumed that topic kits were an effective method of organising science equipment but that they were not necessarily the only way equipment could be organised.

Time

One other direct comparison can be made between the 1985 and 1996 surveys on the question of time. The 1985 survey found that the time spent on science was only 3-4% of the total curriculum time available. The mean was between 40 and 60 minutes per week. From the data gathered by the 1996 survey the time spent on science was 4-6% of the total curriculum time available and the mean was between 48 and 71 minutes per week. Interestingly 44% of schools did either not respond or put a zero for K science.

In the *Review of Primary Science in Western Australia 1980-1985* Betjeman (1985) stated that a new system policy had been formulated and the recommended times were to be 60 minutes for junior grades, 90 minutes in the middle grades and 100 minutes in the senior grades. It is clear that while the average times have increased the majority of schools have not yet reached those recommended by the 1985 report.

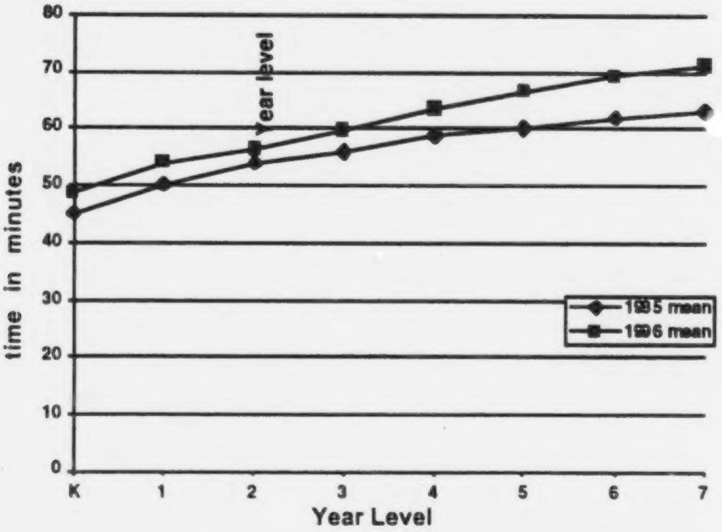

Figure 5. A comparison of the mean times spent on science 1985 to 1996

Conclusions

This study examined school's perceptions of the state of science and the impact of the Science Project on science teaching in primary schools. A second aim of this study was to compare the perceived situation in primary science in 1996 with the situation in 1985. The results describe a generally positive state of primary science in Western Australian government schools. Teacher awareness of the Science Project is quite high. Most schools have sought advice on science teaching issues from district office or central office in 1995/96 and in most primary schools one or more teachers are aware of the Science Project. In about two thirds of schools all or most staff have participated in professional development activities in 1995/96 and nearly seventy percent of schools are implementing a whole school science program. Two thirds of the responding schools said they were using *Primary Investigations* either on its own or supplemented with other curriculum materials. Schools are monitoring science through a variety of tools and with mixed results. They did not necessarily find this information useful.

The comparison with the 1985 survey showed that there has been improvement in many areas. There has been a small increase in the amount of time spent on science by most teachers and this increase is evenly spread across the year levels. There has been a significant increase in the number of schools with identified science coordinators and the number of schools with a whole school science program. Two thirds of schools claim that there has been an improvement in the quality of science teaching and learning in their school compared to pre 1995. This is a significant figure because it represents the positive feeling about science that has been developed through activities undertaken during 1995 and 1996. While a project or program can create a positive attitude to initiate change it is the substantial work that is done in classrooms that will determine whether or not these changes are lasting ones. Many schools chose to comment on the positive feedback they have from their students who are now asking to be taught science.

The survey results indicate a positive change taking place in science as a result of the combination of two factors *Primary Investigations* and the Science Project. The activity facilitated by the Science Project has lead to common understandings of the needs of schools in science. Strategies have been developed and implemented to address these needs. One of the greatest needs was for a whole school science program and *Primary Investigations* has met this need for many schools. Primary science has undergone change since 1985 when it was "in the process of confirming its identity and direction in Western Australia" (Betjeman, 1985, p.42) to 1996 where science has an identity and is setting new directions as a result.

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The Effectiveness and Improvement of Faculty Culture

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Rationale

In 1992, Mitchell and Willower described culture as the way of life of a given collectivity (or organisation), and as a reflection of shared values, norms, symbols and traditions. When applied to a school, the culture will be manifest in the behaviour of the individual teacher, faculties and social groupings within the school (Getzels & Thelen, 1960). Accordingly, the prevailing culture is viewed as having a direct influence on the work of teachers in the classroom and provides the social context for school-wide activities including school development (Stoll & Fink, 1996; Whitaker, 1993). The success of the school in educating students and its capacity for restructuring and development in response to changing environmental pressures both appear a consequence of the culture.

The notion of school culture has evolved from the organisational management social systems theories and the research on school climate. The social systems representation of the school organisation acknowledged the existence of groupings of teachers bonded together by personal and social needs (Faber and Shearron, 1970, Hanson, 1979, Hoy & Miskel, 1987). It was considered that the interaction within a school's social system led to the development of a group climate and norms which, in interaction with personal and organisational needs, was influential on organisational behaviour (Getzels & Thelen, 1960). The notion of school climate was originally investigated by Halpin and Croft (1962), who identified six profiles of organisational climate related to perceptions of teacher and principal behaviour in elementary schools. Tagiuri (1968), conceptualised school climate as the total environmental quality resulting from a combination of physical and social factors including the ecology, milieu, social system and culture. While these developments provided interesting frameworks to view schools, it was not until the early 1980's that links between school environment and student leaning were established. Anderson (1982) reviewed the accumulated research findings on school climate and emphasised the importance of cultural aspects of the school's climate on student learning. Culture was defined to be 'the social dimension concerned with belief systems, values, cognitive structures and meaning' (Anderson, 1982 p. 382). Anderson (1982), also indicated that the relationship between the ecology, milieu and social system dimensions of school climate and student learning was tenuous.

Sergiovanni (1993), advocated a shift in the conceptualisation of schools. He was critical of the application of traditional organisational theories in educational settings and proposed that schools should be conceptualised as communities and not organisations. The difference between the community and organisational conceptions of schools are summarised in the following table.

Organisational Constructs	**Community Constructs**
Formal organisation	Learning community
Organisational structure	School culture
Organisational objectives	Educational outcomes
Administrative processes	Cultural processes
Leadership	Cultural maintenance and transformation
School development	Cultural growth.

Figure 1 . Organisational and cultural constructs

The community conception of schools requires school culture to be considered as the culture of a learning community and not simply as one aspect of the school's climate. It is the culture of the school which provides bonding and cohesion amongst teachers and enables them to work collectively towards improving the educational outcomes of their students. An effective school culture is supportive of the educative mission of schooling and it is proposed that in studying school culture, the focus should be upon aspects of the culture which are conducive to improvements in student learning. Research into school effectiveness and improvement has identified characteristics of the school culture which are influential on improvements in educational outcomes (Sammons, Thomas and Mortimer, 1995; Stoll and Fink, 1996; Stoll and Mortimer, 1995). This paper discusses school culture from a school effectiveness and improvement perspective.

Background

Cavanagh and Dellar (1996) investigated the culture within Western Australian secondary schools. The investigation initially utilised a conceptual framework comprising eight cultural processes which the literature indicated were related to school effectiveness. These processes or 'cultural elements' included teacher efficacy, teachers as learners, collegiality, mutual empowerment, collaboration, shared visions, school-wide planning, and transformational leadership. The conceptual framework was applied in a mixed method investigation of school and faculty cultures which included quantitative and qualitative techniques. The School Cultural Elements Questionnaire (SCEQ) (Cavanagh & Dellar, 1996), was developed from the eight element framework to measure the culture of schools and faculties. The instrument contained eight scales with 64 items to measure prevailing culture and another 64 to measure the preferred culture. Other features included half the items being written in a negative form, a cyclical pattern of distributing the items within each scale and an 'easy scoring' matrix to allow respondents to score their own data.

Following trialing and refinement, the SCEQ was administered in eight schools to 422 teachers. The data from the initial quantitative investigation were subjected to factor analysis during which the original eight element conceptual framework and SCEQ scales were re-examined. This process resulted in a revised conceptual framework comprising six cultural elements and modified seven item instrument scales with improved reliability and construct validity. The quantitative investigation was supplemented by an interview programme in two schools to provide additional information on aspects of school culture which could not be quantified. These included the influence of internal and external contextual factors on the maintenance and change of the prevailing culture.

The overall empirical findings of the study were then incorporated in the development of a model of school culture (Cavanagh, 1996). The School Improvement Model of School Culture (Figure 2) provides a theoretical representation of school culture which can be utilised in understanding and applying the empirical data. The model has six elements which were operationally defined as follows:

> **Teacher efficacy** concerns the belief of teachers in the importance of the social institution of education and the need for school growth which is grounded on pedagogical principles.
>
> An **emphasis on learning** produces a learning community in which there is a commitment to professional growth and improved outcomes for students.
>
> **Collegiality** empowers teachers to exercise professional judgements through the development of supportive inter-personal relationships.
>
> **Collaboration** is interaction between teachers in which information is shared on school operational matters including the instructional programme.
>
> **Shared planning** is a collective process whereby a common vision of the school is actualised by logical planning.
>
> **Transformational leaders** share power and facilitate a school development process that engages the human potential and commitment of teachers.

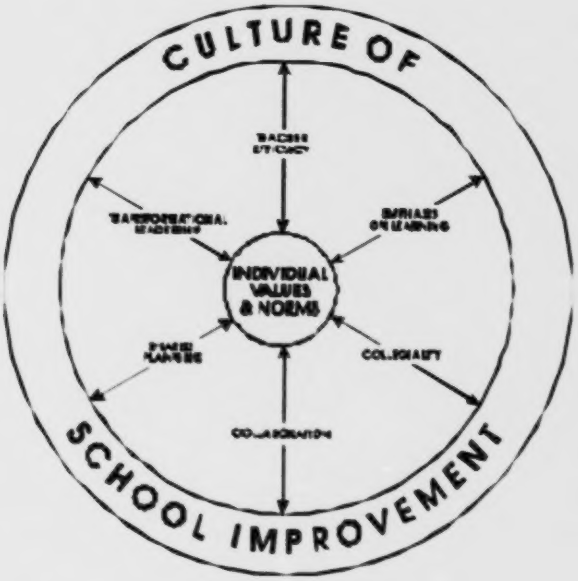

Figure 2. The School Improvement Model of School Culture

These six elements are the vehicles by which the values and norms of individual teachers are shared, ameliorated and consolidated to produce the collective values and norms which constitute the culture. The extent of their presence in a school is characteristic of the culture of the school and when all six are well developed, the school has a culture conducive to the improvement of student learning. The structure of the model also provides a framework for presenting SCEQ data. The six radial components of the model can be used as axes for plotting data to produce a radial graph which represents the culture of a school.

Faculty Based Culture

The processes which have formed and maintain school culture are also present in subject area faculties and the SCEQ can be used to measure the level of the six cultural elements within a faculty and profile its culture. SCEQ data provides teachers with information about their own culture for use in staff development programmes. The theoretical grounding of the instrument in school effectiveness ensures that this information is of consequence to the learning of students in the faculty and consistent with the principles of school improvement. Re-administration of the instrument provides longitudinal data to measure the extent of cultural change in the faculty and to evaluate faculty improvement initiatives.

Examples of Faculty Culture

Figure 3 presents SCEQ data on the culture of two faculties in a large local senior high school, Scottview SHS.

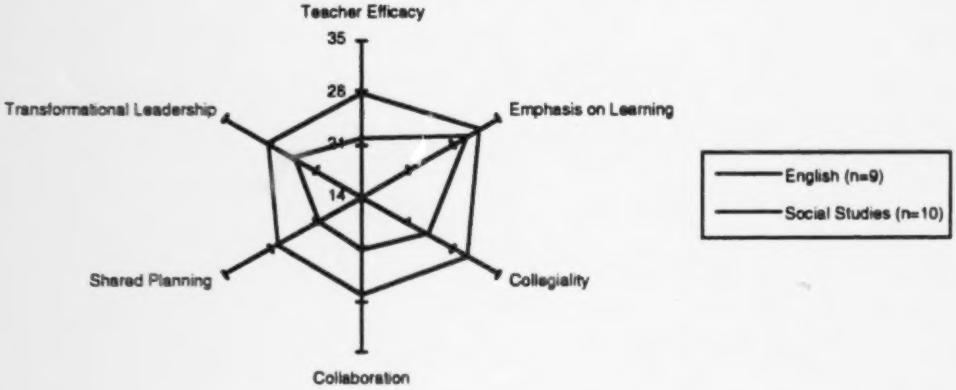

Figure 3. Faculty cultures

The radial graph presents the means scores for the six SCEQ scales. The range of each scale has been set between 14 and the maximum possible score of 35 to make the variations in data more obvious. Single Annova analysis of variance indicated that differences of 2 or more are statistically significant at the 0.05 level. Scores between 14 and 21 result from an average questionnaire response of 'uncertain' or 'disagree', those between 21 and 28 are from average 'uncertain' or 'agree' responses and those above 28 are from average 'agree' or 'strongly agree' responses.

Apart from the 'emphasis on learning' cultural element, the cultures of the English and Social Studies faculties were significantly different. The culture of the English faculty was discussed with the heads of department and they described the faculty as being composed of strong individuals who were often divided over issues and did not work together in a cooperative manner. This is reflected in the low scores for 'collegiality' and 'collaboration'. The lack of cohesion within this faculty also influenced the participation of teachers in school-wide programmes. The individualism in the faculty resulted in its members not being involved in decisions about the future of the school, not participating in 'shared planning'. The low score for 'teacher efficacy' is indicative of these teachers being uncertain about the importance of educating children. The relatively higher score for the 'emphasis of learning' scale suggests that although they may have doubts about the importance of the social institution of education, within their own faculty, student learning and their professional growth were valued. The 'transformational leadership' score relates to their perceptions of school leadership which they perceived as being supportive of teachers and the growth of school programmes. In contrast, the Social Studies faculty was a cohesive team with positive attitudes towards their profession and the learning of students. These teachers worked cooperatively within the faculty and were not isolated from colleagues in other faculties.

Figure 4 presents data which illustrates cultural change and growth within a faculty.

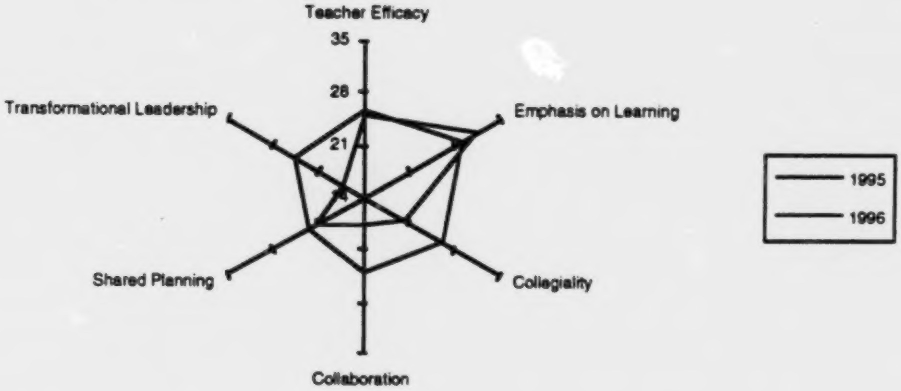

Figure 4. Faculty cultural change

The data were obtained over a 12 month period and corroborated by interviewing teachers. In 1995, the Landview SHS Social Studies faculty was described as being disunited and divided, one interviewee stated that 'collegiality was a nightmare'. Following major staff changes from 1995 to 1996, the faculty developed a new culture which is reflected in the large increases in SCEQ mean scores for the 'collegiality', 'collaboration' and 'transformational leadership' scales. The faculty was described by interviewees as having undergone an 'almost complete about turn'. Interviewees commented on 'increased collaboration, shared planning and collegiality'; 'program writing is done in pairs'; and 'we are working together as a department'.

The previously discussed examples of faculty culture were specifically selected to exemplify the differences between faculties and the phenomenon of cultural change. In general, SCEQ faculty data from six senior high schools has revealed that within each school, there was a diversity of faculty cultures. It also showed in-consistencies in faculty culture for specific subject areas across schools. For example, Science faculties were not all the same. Another finding concerned the stability of faculty cultures. The major change in the culture of the Landview SHS Social Studies faculty was not typical, most faculties experienced only minor changes during the period of investigation.

Summary

The School Improvement Model of School Culture was developed in consideration of contemporary conceptions of schools and the cultural elements which influence their effectiveness in educating students. These theoretical propositions were tested by collecting and analysing quantitative and qualitative data in local senior high schools. The School Cultural Elements Questionnaire provides a reliable and valid means of informing teachers of their faculty and school cultures. Utilisation of a questionnaire for this purpose solicits potentially sensitive information in an objective and non-judgemental manner.

Faculty and school improvement needs to focus on the values and norms of teachers and the culture of their school and faculties. Improvement of the school and the growth of its culture require that teachers understand the nature of their culture and the mechanisms by which it develops, is maintained and changes. The School Improvement Model of School Culture and the SCEQ can be utilised in professional and school development programmes to develop this understanding.

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Mapping the Development of Conceptual Understandings in Primary Science: Some Initial Findings From Three Year 7 Classes

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Abstract

This paper describes the types of teacher-whole class interactions that occurred in three Year 7 classrooms in Western Australia. The researcher provided lesson outlines for the teachers which suggested activities, demonstrations and focus questions, and details of concepts to be developed. Although the lessons were not prescriptive the outlines specified the types of activities that were expected and these included whole class discussions. The quality and nature of these whole class discussions varied between classes. This paper reports the types of interaction that occurred, the participation by class members, the ways teachers developed and elaborated on understandings and the conceptual understandings that were developed by the students.

Introduction

Primary science is often perceived as being poorly taught with many primary teachers lacking confidence and competence in teaching science (Yates & Goodrum, 1990). Teachers may lack content knowledge, particularly in the physical sciences, which may either discourage them from teaching science (Yates & Goodrum, 1990) or may result in restricted or inaccurate content being taught (Carlsen, 1992). Discussions are an important part of science education, but, if the teacher lacks knowledge and confidence, they may be limited and may not develop scientific understandings in children (Roth, Anderson & Smith, 1987). Students often have alternative frameworks of which teachers may be unaware, and which many curriculum packages do not address.

Constructivist psychology indicates that new knowledge is constructed by individuals (Driver, 1989; Wheatley, 1991) and, as it is affected by their current knowledge and beliefs, may result in non scientific understandings being developed (Driver, 1989; Driver & Oldham, 1986). Learners need to be active participants in their learning (Driver, 1989; Driver & Oldham, 1986; Wells, 1989), developing new understandings through social interactions (Driver, Asoko, Leach, Mortimer & Scott, 1994; Solomon, 1993) and activity based investigations.

The Role of Discussion in the Construction of Meaning

Teaching strategies have been designed which are based on constructivism and take into consideration the learner's understandings (eg. Driver & Oldham, 1986; Neale, Smith & Johnson, 1990). These strategies include elicitation of students' held ideas, including probing for deeper understanding; material centred cooperative group work; and group and whole class discussions (Driver & Oldham, 1986; Neale, Smith & Johnson, 1990; Roth, Anderson & Smith, 1987). Whole class discussions need to include open and closed questioning, although closed questions are considered unlikely to develop understanding, and teacher directed discussion where the teacher leads students to correct understandings with links being made to concepts previously covered (Driver, 1989; Gunstone, 1995; Neale et al., 1990; Roth et al., 1987).

The level of teacher knowledge may have an effect on the type and quality of discussion. Carlsen (1992) suggests that teachers lacking scientific knowledge may limit questioning by students, not give clear evaluations of students' answers, and their explanations may lack clarity although they may dominate classroom talk. Teachers with a better understanding of the concepts under discussion may offer explanations which are not at a suitable level for the learners (Ausubel, 1968; Barnes, 1976).

Problem and Significance

Research indicates that to teach science effectively teachers should use constructivist teaching strategies which include activity work, talk within groups and whole-class discussions. Whole-class discussions in primary science classrooms may be limited by the teacher's lack of knowledge and confidence and may lack the type of interactions necessary for developing scientific understandings.

Purpose and Research Questions

The purpose of this study was to examine the nature of whole-class discussions that occurred in three primary classrooms and map the discussions against the changing conceptions of the children in these classes.

The research questions, therefore, were:

(1) What strategies are used by the teachers to enhance discussions?

(2) What understandings are developed by the students and how do these relate to the content, type and quality of the class discussions?

Method

This study examined interactions in primary science classrooms during a five lesson unit of work on the topic of electricity. All teacher-class, teacher-group and teacher-individual interactions in three upper primary classrooms were audio recorded, together with audio and video recording of all interactions and activities of one small group in each class. The researcher remained in the classroom as a non-participant observer during all lessons.

The study was conducted in two Year 7 classes and a Year 6/7 class from schools in semi-rural environments close to Perth, Western Australia. The three teachers, Mr Avery, Ms Brown and Mr Clark (pseudonyms), were experienced and had previously taught electricity as a science topic in Year 7. It was apparent during the course of the lessons that only Mr Avery had a sound scientific knowledge, with the other teachers demonstrating some lack of knowledge. The teachers had quite different teaching styles.

Teachers were each supplied with lesson outlines to cover the unit which were not prescriptive but included background information, activities, demonstrations and focus questions. The lessons, as conducted by the teachers, usually consisted of an introduction which included task directions, materials-centred activity work, whole-class discussions and sometimes a review of the lesson.

Data Analysis

All audio tapes were transcribed by the researcher with long periods of speech by any one person divided to show change of content, eg. from control mechanisms to concept discussions. This was then transferred to a data-base and coded according to defined criteria which allowed the researcher to select needed data.

Results

This section reports the way teachers developed conceptual understandings during whole class interactions with the term 'discussion' being used to describe those periods when the teacher and students were reviewing previous work or treating new work in a whole-class setting. Initially, an overview of the teachers' and children's behaviours during discussions is presented, and this is followed with data regarding students' test results from the three classes.

Types of Interactions During Whole Class Discussion Times

The three teachers had very different styles of discussion. Mr Avery was a friendly teacher, called by a nickname by his students. He conducted animated but quiet discussions and any control mechanisms that he used tended to be incidental and not distract from the flow of discussion. He used practical demonstrations and available media to explain ideas and used analogies effectively. Students usually came to the front of the class for demonstrations where they could easily see what was happening. When questioning students during discussions he used more open questions than the other teachers, requiring students to justify and explain their answers. His students asked non-procedural questions and demonstrated interest in the topic by offering information other than that requested. They were also willing to argue their point of view with Mr Avery. Science equipment was always packed away before the main discussion time, and students were asked to turn and face the teacher. Students were generally attentive during discussions.

Ms Brown was more distanced from the students and conducted discussions that lacked animation and interest. Her control methods tended to interrupt the flow of the discussion. She used few practical demonstrations and, when student models were displayed it was to look at construction and not to develop understanding of concepts being discussed. Students were seated at their desks for all demonstrations and may have found it difficult to see. She used no analogies. She only used open questions prior to activities when students were predicting what might happen, and most discussion was conducted using closed questions. Her students only asked procedural questions and gave limited factual answers with no extra information. They were rarely called upon to justify their answers. Science equipment was always on the desk during discussions and although students were sometimes asked to face the teacher they did not remain in that position. Students were often distracted by the equipment during discussions.

Mr Carter was friendly towards students and had nicknames for most of them. His discussions were animated and fast moving and, although his control methods interrupted the flow of discussion, they were generally less intrusive than Ms Brown's. He used practical demonstrations and student models to help explain concepts, but used them less frequently than Mr Avery. Students moved to see some demonstrations with others held at the front of a seated class. He used analogies effectively. He used more questioning than

Ms Brown although less than Mr Avery, with effective use of open questions. Students were willing to ask questions other than procedural questions, and occasionally questioned points made by the teacher. As in Ms Brown's class, the science equipment was left on the desks during discussions and students, although not always facing Mr Clark, were generally more involved in the discussion.

Development of Conceptual Understandings

One understanding to be developed was the concept of an electric circuit as a set of components joined together in specific ways and at specific places to allow the flow of electric current. During the first lesson the activities and discussions were centred round this concept and there were opportunities to review this in subsequent lessons, particularly in the second lesson where there were opportunities to compare the newly constructed circuits with those produced in the first lesson, and to examine the connection points in a globe holder. Each class was supplied with a wall display diagram which showed a simple circuit and illustrated the path by which electric current flowed through the globe. This was used by Mr Avery but not by Ms Brown and Mr Clark.

During the first lesson Mr Avery specifically discussed the connecting points during three separate whole-class discussions of circuits, working and non-working He demonstrated the flow of current through a complete circuit on one of the diagrams. He also strongly evaluated student comments on the flow of current and repeated student answers. At the beginning of the next lesson he used the simple circuit diagram to demonstrate the flow of electric current through a circuit. The connections were mentioned incidentally near the beginning of the third lesson and later in the lesson it was agreed the circuit constructed was the same as that in the first lesson. He then demonstrated the globe holder and explained how it worked. There was no further specific discussion of the connection points in other lessons, although the poster was frequently used to demonstrate circuits.

Ms Brown made no specific mention of connection points in the whole-class discussions during the first lesson, when students were deciding whether circuits drawn on the blackboard would work, although some students did include battery connections in their explanations of why two circuits would not work. At the end of the lesson, when four more circuits were drawn on the blackboard, Ms Brown described the circuits mentioning connection points to the battery but ignoring the connecting points on the globe.

During the review at the beginning of the second lesson the connections were discussed although the student explanation was ambiguous and Ms Brown only mentioned the battery connections when responding to the student's answer:

Student: Connect one to the positive and one to the negative and then connect the other end to both sides of the battery.

There was no explanation of the connections in globe holders and no discussion as to whether the circuit made in this lesson was similar to that previously made. There was no further specific discussion on connection points.

Mr Clark had three major whole class discussions during the first lesson. During each of these Mr Clark mentioned the connecting points in the circuit but no emphasis was placed on them, and also indicated them on blackboard drawings or models. On one occasion a knowledgeable student described the connecting points in a circuit in a way which was positively evaluated by Mr Clark who then described and demonstrated the circuit using a model:

Student: Having a wire to the bottom of the globe and then the other the silver part or the other bit of globe to the top of the battery

During this lesson Mr Clark also described the current flow through a globe holder. In the second lesson it was agreed that the circuit constructed was the same as that previously constructed and in the third lesson, during the initial review, a student described the battery connections in a circuit.

The mean scores for the pretests and posttests for the whole electricity topic show an improvement in understandings in all classes (Figure 1) with Mr Avery's class showing the greatest improvement in understanding, Mr Clark's class the next greatest and Ms Brown's class showed the least improvement.

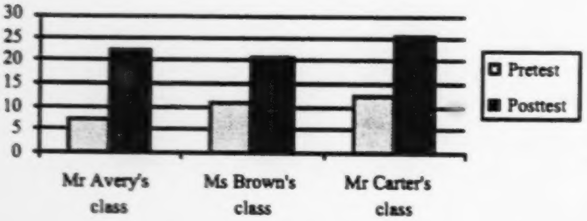

Figure 1. Mean scores of science pretests and posttests (Maximum possible score 59)

The mean scores for Question 7 which probed student understandings of the connection of wires, globe and battery into a complete circuit again show an improvement in all classes from pretests to posttests with Mr Avery's and Mr Clark's class demonstrating a substantial improvement in scores and students from Ms Brown's class showing a limited improvement (Figure 2).

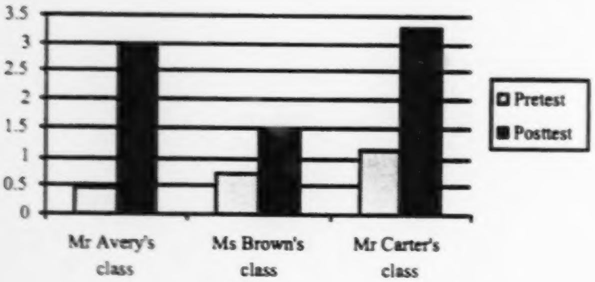

Figure 2. Mean scores on question 7 in science pretests and posttests (Maximum possible score 7)

Table 2 shows the changes in student conceptions of circuits between the pretests and posttests. In the posttest the number of students in Mr Avery's class correctly identifying working circuits in Question 7 increased from 16% to 72%; in Ms Brown's class the increase was from 15% to 28% and Mr Clark's class the increase was from 20% to 63%.

Table 1

Changes in student conceptions of complete, working circuits between pretests and posttests

	Mr Avery's class (n = 25)	Ms Bronw's class (n = 32)	Mr Clark's class (n = 30)
Total students retaining or changing to a scientific conception	18	9	19
Total students retaining or changing to an alternative conception	6	22	11
Total students who retained or changed to no response or informal response	1	1	0

Discussion

Driver and Oldham (1986) and Neale et al. (1990) suggest that teachers need to elicit student understandings so that unscientific conceptions can be addressed during teaching. During discussions all teachers had the opportunity to recognise understandings students held and ensure they were investigated and discussed. Mr Avery probed students' conceptions of circuits and ensured their ideas were tested and discussed. Ms Brown and Mr Clark used a show of hands to decide whether circuits were working, but did not elicit students explanations of why the circuits were working or not. Roth et al. (1987) recognised the importance of open questions and the need to include directed discussion to focus students towards correct understandings. Mr Avery's and Mr Clark both used student answers to develop scientific understandings and evaluated or tested student ideas. Open questions asked by Ms Brown before circuits were tested were never addressed fully after the investigation, with no evaluation of student ideas. Roth et al. (1987) also recognised the need for closed questions as part of the discussion but suggested that an emphasis on only closed questions resulted in less successful outcomes. Ms Brown's limited use of open questions and emphasis on closed questions resulted in little understanding being developed by students. In Mr Avery's and Mr Clark's classes students had opportunities to not only offer thoughtful answers to questions but also to be able to verbalise their ideas by asking questions and disputing points, giving the teachers a deeper insight into student understandings and the students an opportunity to consolidate their ideas (Roth et al., 1987). The limited answers and participation in Ms Brown's class never allowed students, in a whole-class situation, to generate ideas or Ms Brown to recognise differing understandings. Ms Brown was less knowledgeable about electricity than Mr Avery and, as Carlsen (1992) suggested, teachers who have limited background knowledge tend to the limit class discussions and consequently student learning

Links need to be made between activities and student understandings (Driver, 1989; Gunstone, 1995; Neale et al., 1990; Roth et al., 1987) and concepts should be reviewed to ensure they are accepted by students (Roth et al., 1987). Mr Avery and Mr Clark spent time reviewing concepts and this allowed concepts that had previously been treated to be linked with new knowledge. Ms Brown rarely made links between concepts or lessons.

Only one area of conceptual understanding in the electricity topic has been discussed here, but analysis of another conceptual area, where the content and quality of the discussion in Ms Brown's and Mr Clark's class was better than that of Mr Avery's, and students in Ms Brown's and Mr Clark's classes performed better in the test than Mr Avery's students, reinforced the view that the quality and content of whole-class discussion has a powerful influence on the understandings developed by the students.

Conclusion

As a large number of variables impinge on student learning in science classrooms, no direct causal relationship between the type, quality and amount of class discussion and student learning can be inferred. However, the type, quality and amount of whole-class discussion in the classes observed were quite different and these differences are associated with markedly different conceptual development by the children. These data are consistent with social constructivist explanations of the crucial role that can be played by discussion in the construction of meaning.

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Primary Technology: Teachers Concerns and Challenges

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Introduction

The presentation of the Technology and Enterprise Student Outcome Statements established technology as a learning area in its own right, with its own special content and processes. However, no firm guidelines have been developed to provide teachers with assistance on teaching strategies, topics to be developed, or assessment procedures to be used, in the implementation of this new learning area. This paper will present a summary of recent results gained from surveys, questionnaires and interviews, showing the concerns pre-service and practicing teachers have expressed related to the teaching of Technology and Enterprise lessons in their classrooms. The ideas from four exemplary teachers will be explored.

The Survey

The purpose of the survey was to discover teacher's initial concerns when teaching a technology lesson and was designed to be as simple as possible. The survey form was a single piece of paper with eight concerns listed. Respondents were required to rank these concerns in order of importance from 1 being the most important to 8 being least important. The instructions stated:
When about to implement a technology activity in your classroom which of the following factors/issues are the most important?"

The eight factors which were listed were: resources, evaluation, safety, support, cost, time, likely difficulties and personal skills. These factors were derived from several sources. Some were gained by the researcher in informal discussions with teachers and Principals and others from literature published in this area, Treagust, Kinnear and Rennie (1991); Aubusson and Webb (1992); Hoban and Hoban (1992); Eggleston (1992); Clayfield and Hyatt (1993); Anning (1994).

The factors in the survey were randomly listed and the survey administered with little introduction beyond saying the researcher was trying to find out the factors which would influence teachers implementing technology programmes in their classrooms. There was no explanation of why the factors had been chosen, what they meant or opportunity for the respondents to elaborate on the rankings. Four groups of teachers and pre-service teachers were selected by convenience. A total of 169 surveys was completed.

Group 1 consisted of 25 teachers attending a primary science weekend conference. They had chosen a workshop titled "Teaching Technology" which indicated they were interested in this topic. They completed the survey prior to commencement of the workshop. Group 2 consisted of 12 teachers attending a school-based workshop. This was an after-school session at an Independent Girls school where the school coordinator of technology was trying to initiate some interest in this area. At this time the teachers were "acting in a support role to the coordinator, without taking a leading or proactive role in their classrooms."

Group 3 consisted of 12 teachers attending a school- based workshop related to the science package 'Primary investigations'. Group 4 consisted of 124 Third Year pre-service teachers. This group had completed all core units of their course and were preparing for their ten week teaching practice. Four of these surveys were incomplete and deleted from the data.

Table 1

Mean rankings given by four groups of practicing and pre-service teachers

Item	Group1 N=25	Group 2 N=12	Group 3 N=12	Group 4 N=120
Resources	1.80	1.75	2.00	1.68
Time	3.52	3.66	2.08	4.65
Skills	4.48	4.75	3.58	4.90
Cost	4.72	3.66	3.58	6.12
Difficulties	5.00	5.50	6.50.	5.55
Safety	5.08	4.25	6.50	3.78
Support	5.64	6.25	7.00	5.02
Evaluation	5.76	6.16	4.50	4.26

The results from Table 1 show that resources is the factor of prime concern to all groups of teachers. This can be interpreted in several ways as resources may mean equipment, consumable materials, written curriculum materials, or all three. It can also be defined as human resources. Time was the second priority for practicing teachers, which appears to indicate they believe that the planning and preparation of technology lessons may be time consuming. The cost factor is given reasonable priority by the practising teachers, always in the top four. Safety is high on pre-service teachers priorities, which may be due to a perceived lack of confidence in managing classes with all children engaged in active learning. The low ranking of evaluation by the practising teachers is of concern to the researcher as it may be interpreted as teachers not feeling the need to address evaluation at this stage of implementation of the learning area.

The Questionnaire

The questionnaire was devised to gain insights into teacher background, aspects of teaching technology, teachers' familiarity with the Technology and Enterprise Student Outcome Statements and some ideas on the integration of technology and other subjects. There was an opportunity for teachers to make additional comments. As the teachers completed the questionnaire in their own time there was no time limit set. The questionnaire used a mixture of response types, both closed and open-ended items.

The questionnaire was produced following analysis of the surveys. The aim was to focus on the survey responses and to obtain a more detailed picture of the issues and factors teachers are concerned with in implementing this new learning area.

The questionnaire was given to 40 teachers. Thirty of these teachers were studying part time working towards completion of their Bachelor of Education degree, while still teaching full time. They were enrolled in either a science education unit or a mathematics education unit and the questionnaire was given out at the end of a lecture and collected the following week. The other ten teachers were from the primary division of an Independent Girls school and they were given the questionnaire at the conclusion of a one hour professional development session on "Teaching Technology". The questionnaires were completed in their own time and posted to the researcher. The response rate for the first group was 90% and for the second group, 80%.

Results from the questionnaire have been analysed under four sections. teacher background; teaching technology; student outcome statements; and integration of technology with other learning areas.

Section 1: Teacher Background

The experience of the responding teachers is presented in Table 2.

Table 2

The teaching experience of the 34 responding teachers

Number of years teaching	Number of teachers
1-5	7
6-10	11
11-15	10
16-20	6

The above Table indicates the teachers were very experienced, with 80% having a minimum of six years of classroom experience.

The Year Level the teachers were currently teaching is indicated in Table 3.

Table 3

Year Level teachers are currently teaching

Year Level	Number of teachers
Pre Primary	7
Junior Primary (Years 1-3)	11
Middle and Upper Primary	11
Support (different classes)	1
Relief (moving between schools)	4

It can been seen that there was a good spread of responses across the Year levels.

Section 2. Teaching Technology.

The purpose of this section was to try to ascertain at what stage these teachers were in implementing technology within their classrooms. The first question asked teachers to choose which of four levels they thought described themselves. The results are in Table 4. Two teachers did not respond, but both wrote:

"I am not sure what technology means".

Table 4

Teacher's levels of technology teaching experience

Response choice	Number of teachers
Just a beginner	18
Have made a start but need further guidance	9
Have done some activities reasonably successfully	2
Feel confident I know where I am going	3

These data clearly show that at this time a number of teachers are still at the beginning of implementing technology (53%), while another 30% consider they need further guidance. Only 3 (9%) teachers indicated that they felt confident in this learning area, with 2 teachers (6%) feeling that they were reasonably successful. These results were not surprising because the Technology and Enterprise learning area was only designated as such twelve months before the questionnaire was administered and many schools do not appear to be attempting any formal implementation as yet.

The second question in this section asked: What would motivate you to teach more technology? The responses covered a range of areas which could be categorised under five headings shown in Table 5.

Table 5

Motivation required to teach technology

Motivational source	Number of teachers
Resources	17
More knowledge about what technology is	10
Professional development	5
Curriculum materials	3
Time	3

Consistent with the findings from the survey, it is immediately obvious that teachers are finding the provision of resources for technology tasks one of the major difficulties to be overcome in the classroom situation. The responses indicated that 'resources' can mean materials as well as ideas.

Other questions in this section related to the technology being taught, sources of ideas for technology lessons, the documentation used in the planning process, the main difficulties being experienced, the best technology each teacher considered they had done and aspects of assessment. The responses varied but can be summarised as follows:

> **Technology being taught:** 'design, make, appraise' activities; computing; building with Lego; using calculators; and exploring mechanical items.
>
> **Ideas for technology lessons:** other teachers; own ideas, professional development courses; and resource books.
>
> **Documentation used in planning:** daily work pad; programming; 'Primary Investigations'; and Lego resource cards.
>
> **Main difficulties being experienced**: having time to do extended activities; providing enough materials; knowing how to plan appropriately; finding ideas.
>
> **Best technology taught**: making boats from junk; using Lego Technics; building kites; and making spaghetti bridges.

Assessing Technology. Sixteen teachers responded to this item, with only 7 giving a positive response. Methods of assessment included: evaluation of the final product; observation of the children as they worked; listening to children's discussions; use of a checklist, and interviewing children.

Problems associated with assessment were mentioned, such as, time to teach and assess, time to mark final products and the difficulty in making subjective judgements.

Section 3. The Technology and Enterprise Student Outcome Statements

The purpose of this section was to determine teachers' familiarity with the Technology and Enterprise Student Outcome Statements. Four levels of response were provided, as shown on Table 6.

Table 6

Teacher's responses to familiarity with the Technology and Enterprise Student Outcome Statements

Response	Number of teachers
Haven't read it	15
Have skimmed it	16
Have read it thoroughly	3
Have a good understanding of it	0

Table 6 shows that of the 34 teachers in the sample, not one considered he/she had a good understanding of this document and only three had read it thoroughly. 44% had not read it and 45% had only skimmed it. This material was distributed to schools in early 1995, twelve months before the questionnaire was administered, so it appears, from this sample, that little organised discussion has yet occurred and individual schools or teachers are working with the document in some isolation.

Section 4. Technology and Integration

This section tried to find out if teachers were seeing Technology and Enterprise as a separate subject or whether they expected to integrate it with other learning areas. Thirty two teachers responded to this item, with three teachers stating they would teach it separately and twenty six that they would integrate it. A question relating to assessing technology if it was taught in an integrated manner was ignored by 9 teachers. Other responses indicated a lack of confidence in this area , examples included:
"Not sure" ,"You tell me" and *"Good question!"*.

Interviews

Four exemplary primary technology teachers were interviewed to gain insights into their practices when implementing Technology and Enterprise lessons. The interviews contained eighteen structured questions and other non-scripted questions, based on the responses of the interviewee. These interviews produced an extensive amount of data which can only be summarised in this paper.

The teaching experience of these four teachers ranged from eight to thirty years. They were currently teaching Year 1, Year 4, Year 6 and Year7/8. They were all enthusiastic, and indicated they felt confident and competent to teach Technology and Enterprise. and were willing to assist others to gain greater understanding and expertise in this learning area. They were all well conversant with the Technology and Enterprise Student Outcome Statements.

These exemplary teachers were asked what problems they saw in teaching this learning area, so a comparison could be made with responses from the surveys and questionnaires.

These four teachers gave a range of responses to this question on perceived problems or concerns. Two teachers commented on the lack of direction for teachers as to where technology fits into the school curriculum and that many teachers do not understand the philosophy behind technology education. They stated that there was no syllabus and that although there were plenty of 'one-off ideas' available there was nothing that presents teachers with a coherent programme. One teacher mentioned 'teacher apathy' as a problem, with some teachers not wanting anymore change nor wanting to try anything different. Three of these four teachers highlighted the lack of resources and the fact that little money was being set aside for this learning area. It should be noted that the schools where these teachers were working had all allocated some money for Technology and Enterprise activities.

The question of safety was raised but all four teachers considered that technology tasks just required sensible planning and supervision. As one commented, "Technology doesn't introduce any extra safety aspects that you wouldn't already cover in your classroom."

The aspect of resourcing for technology education was discussed and all four teachers saw the provision of resources as essential for technology tasks. Depending on the topic being undertaken the type of resources varied but these teachers mentioned the importance of tools and simple equipment. Items such as glue guns, hammers, nails, and clamps were seen as necessary for construction activities.

The area of assessment was addressed, with each teacher having thoughtful ideas and suggestions on what and how this should be carried out. The importance of 'skilling up' children so they could design, build and evaluate was highlighted. The process the children went through during the completion of a technology task was seen as equally important to the final product and a range of assessment procedures, such as group assessment, peer assessment, use of checklists and observations were all seen as methods of assessing children's progress in this learning area. All four teachers conceded that this was a difficult aspect of teaching technology and that they felt they needed to further consider their methods and strategies.

These teachers all taught technology in an integrated way. Although they often began a topic as a technology task there were always 'spin-offs' into other learning areas, and this was seen as natural and positive.

These four teachers have established practices and styles suited to their individual skills and teaching contexts. They are leading by example and the interviews provided useful information on how exemplary practitioners are viewing the Technology and Enterprise learning area.

Conclusion

This paper has reviewed a study to gauge the concerns of teachers when implementing the Technology and Enterprise learning area. The results show that some teachers have little understanding or familiarity with the Technology and Enterprise Student Outcome Statements, are uncertain how to include technology activities successfully within their curriculum, and see the provision of resources as a necessary requirement for classroom implementation of technology tasks. Some teachers show concern about safety aspects and few indicated any confidence in assessing this learning area. These concerns must be addressed if Technology and Enterprise is to be implemented in primary schools in a well considered and cohesive way. At present there are pockets of exemplary teaching of primary technology and the challenge is to develop these 'lighthouses' so all teachers can gain and build from these experiences and hence all children have opportunities to grow and develop in this significant area of learning.

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Implementation of a Year 10 Bioethics Unit Based on a Constructivist Epistemology

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Introduction

As this century draws to a close, our school students face a rapidly changing and uncertain future. The active encouragement of our students to think critically about ethical issues will enable them to make well-informed political, moral and social decisions about their future and the future of others. I believe that school students need to be equipped with appropriate decision-making skills if they are to contribute to public debate about the ethics of problematic issues such as the arms race, population growth, food and health resource allocation, environmental degradation and control of information technology (Frazer & Kornhauser, 1986; Rubba & Harkness, 1993).

This paper describes the implementation of a Year 10 bioethics unit at an independent girls school in Perth, Western Australia. Bioethics is the study of ethical issues and decision-making associated with the use of living organisms and medicine. Rather than defining a correct decision, it is about the *process* of decision-making, balancing different benefits, risks and duties (Macer, 1994). Bioethics education is about helping students to develop, articulate and evaluate critically their own bioethical values. It aims to make students aware of the divergence of opinion and multiplicity of values that exist in a pluralistic society. Bioethics education also allows students to develop decision-making skills in a climate of respect and tolerance (Reich, 1995). Bioethics education is *not* about imposition of the teachers values and it is *not* about indoctrination of one particular set of values.

There are a range of science topics that can be used to illustrate the role of bioethics in science. The area selected in this study was that of human organ and tissue transplantation. This topic raises a number of ethical issues and thus provides a rich source of dilemmas with which students can discuss, debate and reflect on their own ethical values (Kries, 1992).

When I first taught the unit, I trialled a number of the available resource materials with the main aim of conveying factual information about human organ and tissue transplantation. However, it soon became apparent that there were many ethical, religious and legal aspects that could not be ignored. Indeed, the students reacted very strongly to these issues. They insisted continually on discussing and attempting to clarify these problems. As a result of this response, the development and implementation of strategies for teaching the bioethics unit were undertaken from a constructivist perspective on learning.

An evaluation of the teaching strategies developed and utilised in this unit has been reported elsewhere (Dawson, 1994, in press). In brief, during the development of the bioethics unit, I elected to implement a range of teaching strategies that would maximise opportunities for discussion and debate while, at the same time, provide information and a stimulating learning environment. The most effective strategies were those that were student-centred and co-operative (e.g., role-plays, debates, oral presentations, interviews). That is, the students were engaged actively and explicitly in constructing their own understandings.

Constructivism is a theory about knowledge which recognises that each individual constructs his or her own personal meanings based on his or her prior experiences (von Glasersfeld, 1989). That is, knowledge is not an external 'out there' fact waiting to be discovered or transmitted from the teacher to the student. Rather, 'knowledge is constructed in the mind of the learner' (Bodner, 1986).

A constructivist epistemology acknowledges also that learning is a social activity in which students interact and develop their own meanings through discourse (Driver, 1990; Tobin, 1993). Through discussion with peers, students can clarify their understandings and build on each other's ideas. This perspective does not imply that the teacher should be passive or superfluous. Rather, the role of the teacher is to guide and support students as well as provide a stimulating environment where students will actively learn.

A constructivist perspective seemed to provide a compelling pedagogical framework to enable students to construct their own bioethical values about transplantation. Importantly, the teacher should not impose on students his or her own values, but help students to become critically aware of ethical issues on the basis of their own values and those generally accepted by our society (Skamp, 1986, Mertens & Hendrix, 1990).

Research Methodology

In my role as a teacher-researcher engaged in action research (Kemmis and McTaggart, 1988, p.5), data were generated to evaluate the effectiveness of my constructivist pedagogy. The following research question formed the basis of an ongoing generation and analysis of data which occurred within an interpretive case study framework (Merriam, 1988):

> To what extent were the students empowered to explore their own beliefs and values? That is, did they (a) share control with their teacher, (b) exercise a critical voice, and (c) engage in negotiations with their peers?

The research methodology undertaken in this study was based on a qualitative case study approach (Merriam, 1988). It entailed a detailed examination and evaluation of a specific issue, that is, the efficacy of a constructivist epistemology for teaching bioethics to secondary school students. In this study, the data were interpreted by myself in the role of 'teacher-researcher'. That is, as a teacher, I was actively engaged in research within my own classroom.

The Bioethics unit was part of a compulsory Year 10 course entitled 'Women and technology'. The time allocation for the unit was 10 x 50 minute lessons spread over a single 10-week school term. Data were collected from three classes (termed A, B and C) each containing around 10 students. The names of all students have been changed to protect their identity. Sources of data include questionnaires, student interviews, videotape and audiotape recordings of lessons, informal discussions with students and classroom observations recorded in a personal journal (Holly, 1992). The comparison of multiple sources of data (triangulation) served to increase the reliability (i.e., the degree to which the data can be be replicated under certain conditions) of this study (Merriam, 1988). The validity (i.e., the degree to which the data fits reality) was enhanced by the use of rich descriptions and a consideration of disconfirming evidence.

Constructivist Learning Environment Survey

Students' perceptions of their learning environment were determined using several scales of a questionnaire entitled 'Constructivist Learning Environment Survey (CLES) for Science Education' (Taylor, Dawson & Fraser, 1995; Taylor, Fraser & Fisher, in press).

The CLES questionnaire was administered to all students at the conclusion of the bioethics unit. The purpose of the questionnaire was to determine the extent to which the classroom environment was constructivist. The survey asks students to respond to items related to: (1) the *relevance* of the topic of transplantation to themselves and the world around them; (2) the extent to which students were empowered to express a *critical voice* about the nature and quality of teaching strategies (3); the extent to which students *shared control* in the management of their classroom environment (4); and the extent to which students had opportunities to make sense of their ideas through *negotiation* with their *peers*.

The CLES questionnaire had 35 items (7 for each of the four scales mentioned above) and 7 items related to students' attitude toward the learning activities and classroom environment. Each item has a 5-point Likert-type frequency response scale which comprises the categories: *almost always* (5 points), *often* (4), *sometimes* (3), *seldom* (2) and *almost never* (1). Therefore, the maximum possible mean score of each 7-item scale was 35 (i.e., 7x5) and the minimum score was 7 (i.e., 7x1). The students' responses were analysed statistically using a computer program.

A Comparison of Two Classroom Environments

Below, I describe my experiences with two (out of the three) Year 10 classes, designated Class B (a total of 9 students) and Class C (a total of 10 students). I have chosen to compare these two classes because, although I attempted to create a similar classroom environment in both, students in Class C responded favourably to a constructivist pedagogy, while the responses of the students in Class B were more varied.

Development of a Constructivist Learning Environment

In developing a constructivist learning environment, I acknowledged the importance of students' prior knowledge and values by listening to and accepting students' views on transplantation. I endeavoured to ensure that the students and I interacted on a relatively equal footing rather than a 'powerful teacher' and 'powerless pupils'. Students were encouraged to make decisions on, and to modify the types of learning activities in which they participated. During the unit, students also had many opportunities to engage in verbal negotiation with peers. That is, students were encouraged to discuss, debate and reflect on their existing and developing understandings and values through discussion with myself and their peers.

Class C. During the first lesson with Class C, I explained to students the rationale of the bioethics unit. That is, that the unit was concerned with human organ and tissue transplantation but that, unlike a conventional science class, they would not be required only to listen to factual information and that there was to be no formal summative assessment which required them to memorise 'reams' of facts. The main emphasis would be on identifying and discussing ethical issues which arise in human organ and tissue transplantation. I explained that I did not want them to adopt a particular ethical stance. Rather, I wanted them to think critically about their own views.

Also, I informed the students that I would be collecting data about this unit to use in a research project as part of my Masters Degree. I sought their cooperation in this venture and assured them that any information obtained would be treated in a confidential way. I informed students that they would be helping me evaluate some teaching strategies and that I was investigating whether an 'open' style of teaching was an effective way for students to learn about bioethics. The students were very curious as to what I was studying and why I would want to study. They asked questions about what would be done with the data and who would see it. I answered their questions honestly and frankly. I stated that, "as a teacher, it is sometimes difficult to know whether a teaching strategy is effective or not and that I would appreciate their views on any aspect of the unit".

When reflecting on the lessons with this class, my perception was that the students worked cohesively and seemed to enjoy the topic, the teaching strategies and the opportunity to debate issues with each other. They seemed to be genuinely interested and perceived the topic to be personally relevant to them. For example, during the second lesson, Jemma informed the class that her uncle had died two years ago and that her mother had needed to make a decision about donating his organs.

Class B . As for Class C, I explained to Class B the purpose of the bioethics unit and my intention to collect data for a research project. The students also asked many questions about the purpose of the research and how any information would be used. Again, I assured students that the results obtained from questionnaires, interviews and my own observations would ensure that their identities remained anonymous.

Class B contained four students who, as the unit progressed, displayed an increasingly negative attitude to the teaching strategies and a concomitant increase in disruptive behaviour. The negative attitude of these four students was coupled with a personality conflict between themselves and another student in the class. The demeanour of these students had a retrograde effect on the classroom environment. I was reluctant to quash these four students in the early stages as I wanted them to take responsibility for their learning and behaviour. I hoped that self-discipline or peer-disapproval would modify their behaviour. I had explained to the students that they had control over what happened in the classroom and I believe the four students wanted to test the limits of acceptable behaviour. The behaviour of these students tended to improve when lessons were more structured and focused. They appeared to feel safer and more comfortable when the goals of the lesson were straightforward and explicit, that is, when the classroom environment was closer to their ideal of a 'normal' teacher centred environment.

Constructivist Learning Environment Survey Results

The students' perceptions of the learning environment for each of the CLES scales are displayed in Figure 1. The scales of *critical voice*, *shared control* and *student negotiation* are discussed below.

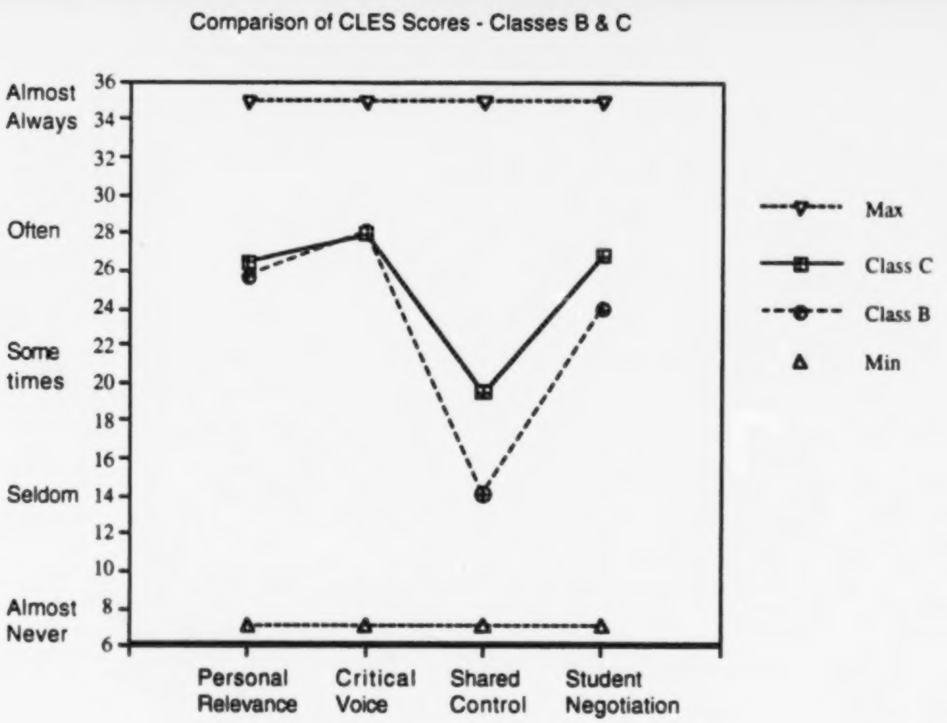
Comparison of CLES Scores - Classes B & C

Figure 1. A comparison of the CLES scale scores in Class B and Class C.

Critical Voice . Students in both classes were encouraged to voice their criticisms and to question the appropriateness of the teaching strategies. In view of my observations of Class B (i.e., a less favourable environment) and Class C (i.e., a more favourable environment), I had expected a marked difference in the critical voice scales of each class. Yet, from the CLES data it seems that both Class B and Class C 'often' had the opportunity to express a critical voice.

What is not evident from these CLES results is the negative way that students in Class B expressed their critical voice. Some of the students in this class were very vocal about the manner in which teaching strategies were used. For example, when the students had been using a personal journal for three weeks, I asked them if they thought the journal was useful in helping them to clarify their thoughts about bioethical issues. The responses of most students were overwhelmingly negative. Although the comments of some students were quite frank and their attitudes 'bolshy', I was pleased that they felt secure enough to question and reject a seemingly inappropriate teaching strategy. After seeking a response from every student, I acquiesced and discontinued the journal. The students did have a critical voice although, unlike Class C, their opinions were often voiced as complaints rather than constructive comments.

After the students in Class C had been using the personal journal for three weeks I asked them about their views on its effectiveness in enabling them to reflect on their bioethical values. Four students said that the journal was a waste of time if it was not going to be marked, although one student pointed out that if it was to be marked then she might not be so honest. Lauren said she would like me to read her journal.

Another student had lost hers. The remaining four students stated that they liked the journal and found it to be helpful in sorting out their ideas and thoughts. The students said they would continue with it only if I requested. We agreed that we should have a vote and, subsequently, we discontinued the journal. Although there was a general negative response to the effectiveness of the personal journal, the students in this class tended to be apologetic about its failure rather than confrontational. That is, they expressed their critical voice in a positive way.

Shared Control. I felt that students were given the opportunity to share control with me to a larger degree than is normally the case in their science lessons. However, the students were not involved in planning, preparing and selecting the teaching strategies which were used in the unit. This was due to the constraints of the second part of this study, namely an evaluation of the usefulness of the teaching strategies in enabling students to clarify, reflect critically on, and modify, their own ethical values. However, as the unit progressed, I actively encouraged students to modify the manner in which teaching strategies were implemented.

For example, when students designed a questionnaire about transplantation, they negotiated the length of the questionnaire, size of working groups, and period of time for completion. Thus, students chose to work under conditions which better suited them individually, rather than under conditions which suited the majority of the class or the teacher.

The CLES results indicate that Class C students perceived that they 'sometimes' shared control with me while Class B students perceived that they 'seldom' shared with me control of the classroom. However, my perception is that both classes were offered similar opportunities to share control of their learning activities. Perhaps the more favourable attitude of Class C students gave them the impression that they had a greater share of control although I offered them the same degree of control as Class B students.

The differences between students' perception of the degree of shared control is especially evident when examining individual students. A student in Class B scored only 7 for shared control (the minimum score possible). Perhaps her negative attitude to the topic and the learning activities led to a feeling of powerlessness over her learning environment. Nevertheless, she scored 32 for a critical voice, so she did not feel constrained about voicing her displeasure. In contrast, a second student (from Class C) scored 25 for shared control and 33 for critical voice. Thus, within the classes there existed a wide range of experiences.

Negotiation with Peers. The CLES data indicate that the opportunity for student negotiation occurred 'often' in Class C in comparison to 'sometimes' in Class B. This result agrees with my observations that the students in Class C were receptive to the comments of their peers, whereas students in Class B were relatively less willing to listen to and respect the views of others. Although, students in Class B voiced their opinions during discussions, they did not seem to listen to, or respect the views of their peers sufficiently. They tended to talk *at* each other rather than *with* each other.

In contrast, as the unit progressed, students in Class C became more willing to share their private thoughts once they realised that their views would be listened to in an empathetic manner. For example, when discussing the format for designing a questionnaire to elicit the views of others on transplantation, Christine, a quiet student, informed the class that she had asked her Form Tutor about organ transplantation and had written down his comments in her personal journal. She was pleased that he had agreed with organ donation and had recorded his consent on his driver's licence. At the end of the lesson she stayed behind to show me her personal journal. Christine's comments prompted Patricia to read from her personal journal about her mother's and father's thoughts regarding transplantation. These tentative disclosures and their non-critical acceptance by myself and other students further enhanced the positive atmosphere of the classroom. The acceptance of students' comments by their peers does not imply that the students' ethical values were similar to each other. Indeed, when students carried out activities where they needed to reach a consensus regarding ethical dilemmas, they spent a considerable amount of time attempting to reach an agreement within their groups.

Discussion

The results of this study indicate that there was considerable variation in the degree to which students benefited from a constructivist learning environment. While most students participated with enthusiasm in all learning activities, some did not. A few students appeared to be unaccustomed to and uncomfortable with the notion that they could be active participants in their own learning.

I believe that the negative attitude displayed by four of the students in Class B stemmed partly from their unease with my new style of teaching. It seems that the suddenness of providing these students with the power to make choices and decisions and have responsibility over the implementation of teaching strategies was stressful for them and they reacted by behaving in a negative and confrontational manner. In hindsight, I have frequently considered whether I could have dealt with this class in a different way. Prior to conducting this study, I would not have allowed students to behave in such a negative way and I would have made it clear that offhand and negative comments were inappropriate. It seems likely that my role as a teacher-researcher placed further stress on these students as it added to their sense of insecurity. I believe they felt that they were being judged or tested in some way and they didn't know how to respond.

The short length of the unit (ten lessons in total) meant that I needed to implement change from the first lesson. If I had taught these students over a longer period of time I may have been able to adjust the rate of change to suit their needs and thus avoid some of the conflicts that arose between these students and myself. At times, their behaviour caused me to seriously question whether a constructivist pedagogy was appropriate. However, my perception is that despite the disagreeable behaviour of this small proportion of students, the majority of students welcomed the opportunity to share control with me, exercise a critical voice and negotiate with their peers. Most of the students were highly motivated and demonstrated enthusiasm for the topic of transplantation and their own ethical values. They participated in all activities with vigour, offered constructive criticism about the teaching strategies, and seemed to enjoy the freedom and shared control which they experienced in the classroom.

Whenever a teacher attempts to adopt a new teaching pedagogy there are likely to be factors which affect its implementation and success. Before I commenced this study, I was aware that students have certain expectations concerning themselves as learners, the role of the teacher, and what constitutes an appropriate classroom environment. For many students (and teachers), an ideal classroom environment is one where the teacher seems to *transmit* knowledge, usually as immutable facts (especially in science), and the student seems to *absorb* this knowledge passively. The teacher manages the students so that interruptions to this process are minimised. Given that the classroom environment that I was attempting to create required the students to reevaluate and significantly modify their well-established roles, it was possible that some of the students may not have viewed a constructivist environment in a positive manner. There was a tension between my desire to enable students to construct their own meaning through dialogue and the students' expectations that the role of the teacher was to provide information. Nevertheless, I have gained invaluable insights into the potential for change towards a more ethical and equitable classroom learning environment.

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The Atomic Model in Science Teaching: Learning Difficulties or Teachers' Problems?

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Abstract

In a grade 9 physics class a teacher introduced an atomic model to the students that was oriented at modern aspects of physics and dispenses with subsidiary planetary orbits. In a test, most of the students described the atom in terms of the Bohr model. This result caused an analysis of the teaching process on the one hand and of the teacher's conceptions of teaching and learning on the other. The results of the investigation support the statement that many learning difficulties students have, when confronted with a modern atomic model, are caused by the teachers' problematic conceptions of learning and teaching and by their inadequate decision making in the course of the teaching process.

Teachers' Thinking: Theoretical background

In many research projects on teachers' thinking the aspect of subject related factors plays a secondary role (Bromme & Brophy 1986; Clark & Peterson 1986; Tobin et al. 1994). But there are some reasons to suppose that both the subject-related instructional possibilities for designing a lesson and the specific learning factors have an influence on the effective orientations of the teacher's acting in a teaching situation. The conditions of learning physics, for example, make demands on the teacher that cannot be compared with those made in other teaching subjects. Therefore it is necessary to relate the general principles and results of the research field 'Teachers' Thinking' to the more content specific problems within a school subject.

Most of the research projects working with science teachers are restricted to the determination of the teachers' conceptions of teaching, assuming a close connection between these conceptions and teachers' decision making. At least for novices this hypothesis has been repeatedly shown to be incorrect (Fischler 1994; Brickhouse & Bodner 1992). A deep gulf between intention and action is a normal characteristic for them. It is not often possible for them to realize their instructional orientations, in principle they have great difficulties to teach according to their conceptions (Artiles et al. 1994). But even experienced teachers often abandon their intentions under the pressure of constraints that emerge in every day work (Lyons & Freitag 1994; Hewson et al. 1994). Because of this discrepancy between intention and action, research activities have to integrate teachers' decision making while teaching into the research design.

In several investigations it has been proved to be beneficial in confronting the teachers with problematic situations shown on videotape and asking them for statements and proposals for possible solutions. In the case study to be described here, the teacher conducted lesson is the starting point for the statements about his conceptions that have been affecting his actions. In most of the investigations concept maps are used to figure out the structure of teachers' conceptions. Some researchers point out that Kelly's repertory grids (Kelly 1955) are a more appropriate tool to get information about the developmental process that leads to the identified conceptions (Pope & Keen 1981; Morine-Dershimer et al. 1992). Repertory grids support a constructivist view which is regarded as helpful not only for the investigation of students' conceptions, but also of teachers' conceptions, therefore it is being used for this research project.

Instruction and Students' Knowledge

The grade 9 students described in this paper have been observed and questioned since grade 7: Observations during lessons, questionnaires, and interviews in groups are expected to provide information about the development of students' conceptions concerning the particulate nature of matter. The following teaching sequences were recorded and questionnaires were administered:

Chemistry Topic: Development of Atomic Models.

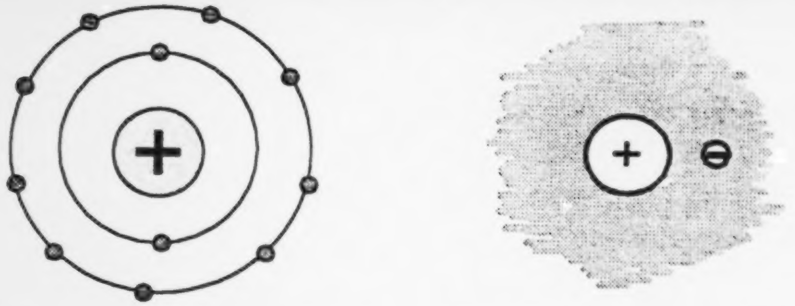
At the beginning of the first lesson a female student reports on the historical development of the atom models. At the end of this presentation the teacher asks whether he should dictate a summary. The students accept this offer thankfully. In the last 20 minutes of the lesson the teacher covers the Dalton model. In the second lesson the teacher continues the dictation. For half an hour he describes the Bohr model in detail. An illustration shows the electrons as thick dots in drawn orbits. The teacher explains: 'Orbits of electrons that have the same distance from the nucleus are called shells.' In the third lesson names and properties i.e. mass and charge of the particles in the nucleus and in the shell are listed systematically. Finally, in the last of the four lessons the structure of several different types of atoms are described in diagrams of the Bohr model.

Physics Topic: Electric Current in Liquids and Metals; Electrons and Ions.

The aim of these four lessons is the explanation of conductivity by means of the electron model. First the conductivity of electrolytes is explained: Negatively and positively charged ions move to the electrodes. With the help of the Edison Effect it is brought out in the next two lessons that the moving charged particles are negative and known as electrons. In the last lesson of this sequence the electron conduction is described in detailed illustrations: It shows a positive nucleus of large mass in an environment that is shaded without boundary, in which the electrons are located and the movement of the electrons is not brought into question (Figure 1).

Class Test After the Chemistry and Physics Lessons

"Describe the atom model talked about in the physics lessons, possibly with a drawing", is a task in the class test after the lessons in chemistry and physics. Most of the students drew and described the Bohr model as it was drawn during chemistry instruction. Electrons were drawn as particles in orbits with the nucleus in the centre. Some students kept in mind that the first complete 'shell' contains two electrons and the second 'shell' eight electrons. In some mixed forms the drawing of the physics lessons is presented while the verbal description mentions the orbits in which the electrons move.



Atomic model in chemistry lessons   Atomic model in physics lessons

Figure 1.

Teacher W.: Conceptions of Teaching and Learning

Teacher W. has taught physics in the same class since the beginning of grade 8. He had taught the four physics lessons on electrical conductivity and formulated the class test. In the intial part of the interview he was first questioned about the instructional principles that have been decisive in his teaching, first in reference to the four lessons, then to his teaching overall. The second part of the interview focussed on the construction of the repertory grid. In a further interview teacher W. had made statements on the presented analysis of the repertory grid. Finally, in a third interview, he was asked to comment on the summary made by the researcher.

The Particulate Nature of Matter and the Atomic Model

The interview with the teacher begins with the question with what intentions he has started the four lessons. After having listed some topics and ideas that for him have been in the content related centre of the lessons (electrical conduction in electrolytes and metals, surplus of electrons, Rutherford's atomic model) the teacher (T.), at the very beginning of the interview, describes a goal that is obviously of great importance for him:

T.: 'The intention was that the students somehow learn the model structure of conduction, that it is not possible to look into it, only indirectly. That one creates patterns of explanation that have the character of a model. That is not to say that there are small spheres that move here and there, but we can imagine it so or so ...'

Two sentences later the interviewer wants to know more exactly what the object is that students should form a model about:

T.: 'Yes, conduction processes. Of course, this later on simplifies the reflection of the electrical resistance, when it is clear to the students how the charged particles move in the conductor.'

In this statement the teacher does not talk about a model. This would be more the case with a formulation like: '...when it is clear to the students which idea one has of how the charged particles move.' Not only in the dialogue with the interviewer who as an expert knows what the teacher talks about, but also

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in the lesson, when he gives explanations to students who have even to learn what a model is, the teacher uses the short form that replaces the careful description stressing the model character by a realistic phrase:

T.: 'Therefore, what does the atom look like now?' (T. draws an illustration)

'This is, we have a positive nucleus and around this - which colour should I choose now, I pick blue, around this a negative shell in which electrons are.'

Maybe it is the physicists' slang that prefers short descriptions, but perhaps it is the opinion that it is not always necessary to speak of models, almost never necessary where topics of students' learning are concerned. The possible interpretation of the teacher's statement will again appear later on.

In the lessons the teacher had stressed neither the particulate nature of the charged particles nor the model characteristics. The interviewer (I) draws the teacher's attention to this discrepancy between the stated intention and the actual teaching of the lessons. His reaction clearly shows a pattern of arguments that can be found quite often with teachers:

I: 'The Edison Effect could be explained also by means of a continuum of charges. How do you justify to the students that there are electrons?'

T.: 'For the students the particulate nature of matter is quite clear. The teacher had taught this subject last year.'

The teacher's idea that a topic already taught is remembered by the students even one and a half year later, is a commonly held belief. Here, there is also the fact that the teacher underestimates the problems that the students have with the conception of the particulate nature of matter. Also on this point the teacher is in accord with most of his colleagues: They do not consider it to be possible what the results of numerous investigations verify, namely, that on the way to learning the concept of particles the students stop at various intermediate concepts. These intermediate concepts are interwoven with ideas about particles that have properties like matter has, for instance colour and temperature.

Because the interviewer is not convinced of this long-term learning effect, he asks once more:

I.: 'Do you think the students have understood that this is a model generated by us?'

T.: 'This is a long-term concern. The goal of the single lesson is the electrons' movement. This is the immediate goal. The other is the long-term goal, an objective that can be considered only over a long-term.'

This statement can be heard quite often. General intentions that are not directly related to concrete subjects seldom are the focus of teachers' thinking. The reference to the long-term character of the goal sounds like an attempt to put off an inconvenient theme. The experiences, so far, do not exactly encourage him to a more logical position.

In a short part of the interview it is the judgement about what kind of learning processes are to be assumed behind the students' discussion on the Edison Effect:

T.: 'This I have noticed quite often when we have discussions. They consider it as an amusing diversion. They prefer to calculate with a formula rather than to participate in such a broad discussion. I have already observed this in grade 8 when we also worked on the particle model.'

It is the teacher's experience that the students do not appreciate such discussions, at least they do not accept their seriousness. The observation in the chemistry lesson mentioned above where the students, let off the task to actively work on the discursive development of various atomic models, very delightedly accepted the teacher's offer to dictate in detail, and this observation confirms the physics teacher's judgement: The students have a conception of physics and chemistry teaching which fits the learning of facts and writing them down more than the thinking and talking about the phenomena presented.

Unusual for an experienced teacher is the idea that overestimates students' ability to abstract:

I.: 'In the chemistry lessons the Bohr model was definitly presented to the students. In the physics class test the students fall back to a considerable extent to the drawings of the chemistry lessons. No student described the drawing presented by you, that is a nucleus surrounded by an electron cloud.'

T.: 'Actually, I am a little amazed. The students have held a little to the concrete form.'

It is not surprising that the students do not recall the physics teacher's drawing at all, but that the teacher assumes that the students would draw a model different from Bohr's (nucleus, electrons in orbits). In the second interview the teacher justifies his astonishment. The Bohr model would contain much more information than the model drawn by him (nucleus and area for electrons). He had rather assumed that the students would remember the rather 'simpler' model and be able to repeat it. Obviously the teacher considers the influence of concrete pictures that are oriented at mechanical models as being lower than it really is according to all research results concerning the topic 'atomic models'.

Summary

The statements in the interviews and the judgements given for the repertory grid draw a net of interrelations between teaching principles, expectations and judgements. They refer to the teacher's general conceptions of teaching and learning in physics lessons as well as to his opinions about the treatment of the topic 'particle structure' in the classroom.

It is remarkable that an instructional principle that is provided with high priority undergoes such decisive restrictions. There is a gap between intention and action that, above all, is caused by the discrepancy between the desired and the experienced reality of teaching. In the initial statements and with accentuation teacher W. speaks about the *Emphasis on model structure* as the most important instructional intention, at the very least, for the four physics lessons in which the electron model for electrical current was marked on. However, the teaching conditions outline narrow limits for the realization of this intention and activate the doubts that the teacher had anyway.

The most important factors within this conflict between different goals are content specific on the one hand and have general aspects which are independent from special situations or topics on the other hand. Listing them and commenting on them provides a summary of the teacher related problems on the way to teaching the atomic model. It is obvious that students' deficient learning results are partly caused by the teacher.

Content Specific Aspects

Missing Appropriateness in Teacher's Speech - or: Hidden Realism?

Even Copernicans say: 'The sun rises in the East', knowing very well that the earth turns toward the sun. But as it is with this example, so it is also in the field of thinking in models, where a verbal inaccuracy makes those students more unsure who have their problems with the understanding of the physical view.

Physicists and physics teachers often convey the impression that they merge model and reality not only in descriptions but also in their thinking, at least when an explicit reflection on aspects of the philosophy of science is not required. The reason for this is probably the attitude of teachers and researchers in physics towards a more realistic view. The emphasis on the model structure of physical descriptions in physics teaching would then be a process of adjusting to instructional principles that do not necessarily correspond to the teacher's conceptions about the philosophy of science.

The Teacher's Experience with Students' Attitudes Towards Models in Physics

'Students want to know how it really is,' the teacher states. That means the students are not always able to understand that the existing knowledge does not allow a description except a model oriented one, if no inadmissible conclusions have to be drawn. The careful inferences in physics surely have to be practiced; in any case, for students it is by no means a matter of course. The stronger interest in 'how it is' and not in 'how one has to imagine it' probably is connected with the students' aversion to the discussion about interpretations and models in the classroom. Therefore they are not willing to follow the teacher into a discussion about these kinds of questions within the philosophy of science.

Underestimating the Efficiency of Illustrative Models

For the physicist an illustration is only a visualizing intermediate step and a current support on the way to a deeper understanding of a content. For the student it quickly becomes the final description because he or she does not have success in managing the following abstraction. Expecting a foreseen failure in this work of abstraction teachers often - so to speak as an anticipation with resignation - carry out a restriction on a visualized level of description and how it happened to the students of this case study in the chemistry lessons. The problems that teachers get for the long term, with such short-term assistance for learning, are generally underestimated.

The Teacher's Ambivalent Attitude Towards the Instructional Principle 'Particle Structure'

The preference for this instructional guideline that becomes apparent in the first words of the interview obviously conflicts with the reserved judgement in the course of the conversation and in the repertory grid. In the teacher's opinion the students have a lack of interest in the discussion about this important principle. Therefore, it gets properties that, in the teacher's perspective, suppress motivation and hinder learning. It is not realized as a guiding line for the teacher's decision making against his own pedagogical conviction.

General aspects: Teaching and Learning in Physics Lessons

Long-term Goals in Individual Lessons

Probably, it is the fate of many of the goals formulated in general introductions that they are highly accentuated as being important for physics education but come into the background in the daily teaching process in which concrete topics and tasks dominate. The slow development of an appropriate understanding of models' function and scope presumably belongs to these goals, although there exist many contexts that are suitable for such discussions.

Teachers' Conceptions of Students' Physics Learning

Novices particularly have conceptions that consider learning as single events and therefore do not think much of repetition and practice. Experienced teachers have gathered many examples that physics learning is much more difficult and that often enough regresses come about. Yet it can be observed that even experienced teachers do not always actualize all of the learning problems as they appear in empirical investigations. Often many of the students do not have the possibility to ask or the time to work on what is presented. The teacher's intention to progress in treating the topic leads to a situation in which individual students' answers are too quickly regarded as a result of physics learning even though the knowledge is poor. Therefore, often feedback to the majority of the students does not occur.

In this case study the teacher has not passed over students' learning problems thoughtlessly but he surely was too confident that his explanations would fundamentally and permanently change students' existing conceptions about the particle structure of matter and atoms.

About the Dilemma in Physics Teaching: Demands on Physics Learning and Students' Readyness to Learn

The teacher's categorization of the instructional principle *'Heeding students' understanding of the used terms'*, shows two competing criteria the teacher cannot bring together. As an element in the repertory grid this principle is regarded as essential for teaching which promotes physics understanding, but at the some time as unsuitable for the realization of good physics teaching. The instructional intention *'Emphasis on the model structure'* has come out of this evaluation as well. This can be an indication of the teacher's failure in working up the content related instructional aspects of this topic.

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The Application of Constructivist Learning Strategies to the Redesign of the Lower Secondary Science Curriculum

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Introduction

What convinces a stable well organised group of science teachers in a government high school to throw away the existing Unit Curriculum structure for the Year 8 course and experiment with not only a new course structure but also a new teaching/learning philosophy? How easily do teachers accept and use the constructivist learning model? How has the change in course structure enabled teachers to take risks and develop their pedagogical skills. These are some of the questions that I have asked myself many times since the decision by the Science Department staff at Armadale Senior High School to change the Year 8 course. I hope that in this reflective history of what has happened at our school some of these questions might be answered.

Why Did We Change?

We recognised need for change in the way we were teaching and what we were teaching at a breakfast meeting held in mid 1994. We decided as a department that firstly the science that we were teaching had to be made more exciting and more competitive with the stimulation that students received from such sources as home entertainment technology. Whether or not we achieved this aim the changes that resulted from these thoughts led to the introduction of more investigative activities within the Unit Curriculum courses, an inclusion of these as part of the assessment structure, and a consequent down-grading of formal testing. During 1995 we often commented to one another on the success of these investigative activities in terms of the student enjoyment and the opportunities which arose for teaching scientific skills.

When I moved to Armadale Senior High School in 1994 I had been teaching for 17 years. In my 'previous life' in England I had been a Head of Science and had been involved in the writing of the Schools Council *Exploring Science* series and the rewrite of the *Nuffield 11-13* series. After six years of assimilating what I thought was the Western Australian way to teach science I was ready for a change.

At the beginning of 1995 I was still unhappy with some of the material that we were teaching. In particular I felt that the non-academic year 10 students were becoming increasingly alienated by what I thought was a watered-down version of a preparation for potential T.E.E. students. After discussions with the Head of Department and other teachers I was encouraged to apply to the *Science Teachers Leaders Course* so that I could do something useful instead of just whingeing". After years of stagnation the course blew away the cobwebs and very quickly convinced me of the benefits of adopting a constructivist philosophy. It seemed to me to fit with the ideas of Kuhn and Popper that I had read many years ago, and made such good sense that it should be used immediately to improve the way young people are educated. I could see many ways to make use of constructivist learning strategies in my own classroom and indeed began to trial some.

I also felt that all the time and money invested in putting me through the *Science Teachers Leaders Course* would be wasted unless I in someway transferred some of my own development to the teachers at Armadale. In any case if I wanted to change what I was teaching and the way I taught then I could not do that in isolation.

Just as we began to make some tentative plans for minor changes on the basis of some trials of some of the constructivist strategies midway through 1995, we were struck by the dazzle of *Primary Investigations* coming over the horizon. We realised that more than half our Year 8 intake in 1996 would be coming to us having experienced this new science course. As a staff we were not even sure what *Primary Investigations* was, but we did know that we could no longer carry on with our existing science program without taking external changes into account. Indeed we asked ourselves how new Year 8 students would view what we were then serving up as science compared to what we had heard was a 'purpose built' investigative science course.

Finally two other Teacher Leaders began to influence my views in relation to implementing some meaningful change that would utilise our recently gained knowledge as well as benefit both the teachers and students at our respective schools. The three of us decided to form a cooperation pact to share whatever we produced in our schools, with a specific focus on the Year 8 curriculum. It just so happened that the two other teachers were Jeff Medcalf from Albany Senior High School and Chris Watts then at Hedland Senior High School, so we could not have been much more widely separated.

How Did We Implement Change

The decision to attack the Year 8 curriculum was an obvious choice. There was less risk in tampering with what the new intake would be doing and whatever damage we did could be repaired in later years. We were concerned about students losing interest in science during Year 8 so there was a hope that the course that we came up with would maintain their enthusiasm. By working on the Year 8 curriculum we could form a network with Albany and Hedland Senior High Schools, and thereby share the preparation of work schemes between the three schools.

The next step was to find out more about *Primary Investigations* so that we could better prepare for the transition of primary students into high school science. The Armadale District Staff Development Officer, Scott Harris, arranged for our entire Science Department to attend a *Primary Investigations* professional development session at Challis Primary School. All of the secondary teachers were impressed by the thought that had gone into the preparation of the materials that made up the course. The kind of activities that we had begun to dabble with were strung together into a learning progression that was being applied by non-science teachers. The way that simple equipment was used to produce challenging problems which involved imaginative thinking in the search for a solution began to make us all think about what was possible. A couple of the Armadale teachers were particularly taken by the 5 E model for the structure of the learning progression in *Primary Investigations*, and its influence arose later in the story.

Another benefit of the morning spent at Challis was the chance for specialist secondary science teachers to talk with primary teachers who happen to be teaching some science. Our view of the purpose of a science education was altered after hearing how primary teachers felt that science was offering an across the board development of skills such as group cooperation, organisation, recording, and problem solving. Every primary teacher already using the package stressed the magic ingredient of enjoyment, questions about motivation were no longer relevant.

We were all 'fired up' by what we had seen at Challis although we knew that we needed a program with a greater degree of flexibility for the individual teachers while maintaining or taking further the investigative flavour. The next step was to design a program for term 4 of 1995 for the writing of some themes or topics and the professional development that I felt was needed to enable us to achieve our aims. These aims or outcomes were:

- The students should be enthusiastic about Science after a year of High School Science.
- The transition from Primary Science to High School Science should be smooth.
- The learning involved in the Year 8 course should act as basis for further courses in Science.
- The activities and strategies involved in the course should be student centred and based on constructivist principles in order to promote an effective learning environment.
- The content of the course should be relevant and allow access to all students. It should be their science or at least seem to be so.

Table 1 shows the program which the Science Department worked through during the last term of 1995. This program formed part of a submission for contract payment from the Education Department of Western Australia which encouraged the group by the official recognition that what we wanted to do was worthwhile.

Table 1

Program of curriculum development activities

Time	Target
Week 1	Constructivist science teaching. Divide into working groups to prepare topic descriptions.
Week 2	Comparing the topic descriptions with the Outcome Statements and drawing up a list of *possible* outcomes for each topic.
Week 3	Prepare a more detailed description of the content and begin to plan activities.
Week 4	Workshop on possible strategies e.g. P.O.E., concept maps, problem solving, experimental design, anomalous events, etc.
Week 5	Complete planning and preparation of activities, and review topic description.
Week 6	Review possible assessment strategies and plan assessment items. Strategies could include: portfolios, quizzes, concept maps, investigative activities, etc.
Week 7	Whole group editing session.
Week 8	Finish each topic to the following plan: • Topic description • Possible outcomes • General overview - including: rationale, content, activities, and learning strategies. • Assessment items.

Topic Titles: What's cooking
Small world
Where there's smoke.........!

The first meeting was scheduled for a one and a half hour session after school, which in my own mind I had divided up into a half an hour for talking about the constructivist learning model and one hour for organisational matters. In fact nearly the whole meeting was taken up with the discussion of constructivism and the organisational issues concerned with writing teams were squeezed into the last ten minutes. The writing program was constructed as a blend of the activity of writing and 'formal' professional development due to my wish to share my experiences and knowledge from the Science Teachers Leader program with my colleagues. The relevance of the professional development components of the program became obvious as the teachers began to write and attempt to put together a course based upon constructivist principles.

The Structure of the Topics

The writing teams were given complete freedom in terms of the structure of the topics that they were writing. The group that I was involved with chose to emulate the story led theme idea that is employed in the Curriculum Corporation books such as *What Happens When You*.... During our first meeting before school one morning we began by brainstorming the concepts which could be connected with the title *Where There's Smoke*...... and then used these ideas to construct a flow diagram of how these ideas might be put together into a course. Part of the rationale behind our thinking was that the learning program should be negotiated with the students once they were drawn into the topic through the initial activity. For example when I taught this topic I began with the potassium permanganate and glycerol demonstration, which led to a discussion about how easily fires can start, and then on to the students own experiences with fire. We knew when we first thought of this topic that Armadale children would often encounter bushfires in their semi-rural environment, providing them with a variety of rich experiences. I asked them to write about an adventure with fire which could be fact or fiction and then we discussed what they could study in order to know more about fire. We then constructed our own flow diagram for the topic.

The next stage in writing the *Where There's Smoke*..... topic was the listing of possible outcomes, based on the draft S.O.S. and listing the possible activities through which the outcomes might be achieved. Then it was down to the 'nuts and bolts' of finding resources for the topic, writing worksheets for activities, trying out activities(especially for safety) and planning assessment strategies so that we met the target outlined in the Week 8 box of the writing program.

The other groups worked differently. In particular the pair writing What's Cooking? decided to organise the learning progression for the topic around the 5 E version of the constructivist learning model from *Primary Investigations*. The 5 Es stand for engagement, exploration, explanation, elaboration and evaluation. The students were *engaged* by being posed the problem of winning a competition to produce the best toffee at a local show by adapting what they already know about toffee making. They then had to *explore* through predicting, trialing, testing and modifying their champion recipe working in a scientific way to achieve the best result. This best result was assessed by the student's parents for toffee made at home by the student. The *explanation* took the form of library research on questions that the previous phases had generated, and at a level determined by the abilities of the students. *Elaboration* took the form of the preparation of an oral presentation demonstrating solutions to the problems faced, new knowledge gained, and any conclusions arising from their work. The *evaluation* came from the oral presentation which was assessed by their peers, the parental assessment of their product and other assessments that the teacher required in order to decide the students level of understanding or achievement.

We felt that these two topics, together with *Small World* showed a wide variety in format but the use of a 'jigsaw' structure for a classification topic from the Albany writing group widened our horizons further. From large home groups the students were divided into expert groups of four to research one of the major plant groups such as algae, ferns, angiosperms and so on. Each expert group had to provide a cloze exercise, an unlabelled diagram, four questions for a quiz or test, and another activity to use with their home group. Our school librarians were so impressed with the way that the students worked that the whole activity has been shown around by the school Stepping Out coordinator as an example of good practice. The students then went back to the lab. to work through their activities with their home groups and I was redundant! Or rather I was able to work with some individuals because the groups did not want me interfering with their teaching. I was astounded by the speed with which the students could become independent learners, the only negative aspect being the very difficult fact based questions that they produced.

Freedom Through Structural Change

Apart from the writing of new topics to suit a constructivist approach to learning, a vital ingredient of the success that we have had has been due to the change in structure of the year 8 course.

Firstly there was no time limit. We agreed from the start that a teacher or class could choose to achieve the outcomes for year 8 by working through just one of the topics if they wished. This means that there can be no time limit and that the teacher has the freedom to follow a particular interest or the development of a concept until they see fit to end the topic.

Secondly there was a free choice with the type of assessment that teachers could use. Some teachers still wished to use formal testing for some of the topics, whereas others used the full range of portfolios, oral presentations, informal discussions, observations, display work, model building, and open-ended investigations. In order to achieve this liberation in assessment we discussed the need for confidence in teachers professional judgements of the level of achievement of students rather than having a formal system of comparability based on numbers. This was particularly important as we were trying to move to a system of combining the assessment with the teaching progression.

Lastly the administration at Armadale helped by removing the unit numbers and titles from the reporting system and replacing them with 'Science semester 1', 'Science semester 2'. A small but significant change.

Summary

By adopting a constructivist learning model and freeing the teacher from the constraints of time lines and set assessment structures, we have changed the science curriculum at Armadale Senior High School.

These changes allowed teachers to experiment with new pedagogical techniques, learning strategies and assessment strategies in a low risk environment. The three major pedagogical skills, negotiating, group work and thinking on your feet (Hand and Vance, 1995) have all been explored by all the teachers involved in the new year 8 course. Although there have been many teething problems not one teacher has declared that they would rather teach the unit curriculum. The further development of the topics and articulation of the course as a whole is providing an avenue for additional professional development in an active and concrete way. We are also convinced that what we are doing is better for the students and after all that is the bottom line.

Acknowledgment

I would like to thank and pay tribute to the teachers of the Armadale Senior High School Science Department for the dedication and energy they demonstrated in writing and teaching the new year 8 science course.

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Development of an Interactive Multimedia Package Designed to Improve Students' Understanding of Chemical Equations

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Abstract

Research indicates that students often fail to develop acceptable levels of understanding of chemical phenomena. Chemical equations and their interpretation is one aspect of chemistry where levels of understanding are limited and students often hold inappropriate alternative conceptions. One factor which contributes to student difficulties is the presentation of chemical equations at three levels: the macroscopic, the submicroscopic or particulate, and the symbolic. This paper describes the development of interactive multimedia materials designed to improve students' understanding of chemical equations. The materials include three modules dealing with molecular equations, ionic equations, and interpreting equations. The molecular and ionic equations modules include demonstration videos, particulate simulations, and instruction, with feedback, on writing balanced equations. The module on interpreting equations develops students' skills in interpreting equations by providing them with exercises which require them to work with equations at a particulate level.

Introduction

Alternative Conceptions Research

Research (Garnett, Garnett & Hackling, 1995; Nakhleh, 1992) indicates that it is very difficult for beginning chemistry students to develop adequate conceptions of the unobservable entities (atoms and molecules) and events involved in chemical reactions. The inability of students to visualise the submicroscopic particulate nature of matter and the processes involved in physical and chemical change represents a major barrier to students developing a scientifically valid understanding of many chemistry concepts. As a result, beginning students commonly exhibit a wide range of alternative conceptions concerning the molecular basis of chemical reactions and this subsequently affects their ability to write balanced equations, interpret the symbolic representations used in equations and solve problems based on equations. These alternative conceptions, as well as being an important concern in their own right, are also important in that they limit students' ability to interpret subsequent phases of instruction, particularly in a hierarchical subject like chemistry.

Several studies have investigated students' understanding of chemical equations and the processes they represent (eg. Garnett, Hackling & Vogiatzakis & Wallace, 1992; Ben-Zvi, Ceylon & Silberstein, 1987; Yarroch, 1985). Some of the alternative conceptions evident from these studies are listed in Table 1.

Table 1

Students' alternative conceptions: Balancing and interpreting chemical equations

1. Subscripts in formulas are numbers used in balancing equations (and do not represent atomic groupings).
2. Equation coefficients are numbers used to mechanically balance equations (and do not represent the relative numbers of species reacting or being produced in chemical reactions).
3. Chemical equations do not represent chemical reactions at a particulate level.
4. Chemical equations do not represent dynamic processes in which molecules/particles react with one another to produce new molecules/particles by rearrangement of the atom.

Yarroch (1985), in a study of Year 12 American students, found that about half the students who were able to balance chemical equations were unable to draw a reasonable diagrammatic representation of the equation at a particulate or molecular level. Students often drew representations which, while consistent with the total number of atomic particles involved, were inconsistent with the formulas of the substances involved and the coefficients in the equation. Yarroch concluded that many students had inadequate conceptions regarding the meaning of formula subscripts and equation coefficients. Students often regarded these as numbers distinguished by their location in an equation, and used to balance the numbers of atoms on both sides of the equation, but had little understanding of their chemical significance.

Ben-Zvi, Eylon and Silberstein (1987) found that substantial numbers of Israeli students also held inappropriate conceptions about both structural and interactive aspects of chemical reactions. Students commonly represented the molecular compound Cl_2O as two fragments, Cl_2 and O; and failed to distinguish between N_2O_2 and $N_2 + O_2$ when considering possible products of a reaction between N_2 and O_2. Student difficulties with the interactive nature of chemical reactions are illustrated by the reaction between N_2 and O_2; some students thought N_2O_5 could not be formed because of the need for three additional O atoms; others thought NO could not be formed because the mass of the products would be less than that of the reactants.

Garnett et al. (1992) investigated some Year 10 Australian students' abilities to balance chemical equations and apply an understanding of equations to 'simple' stoichiometry problems. As reported by Yarroch (1985) students were often unable to draw diagrammatic representations of equations and many students showed a lack of understanding of the different use of subscripts in formulas and coefficients in chemical equations.

In this study students also had considerable difficulty when asked to formulate an equation which described the reaction represented by 'before reaction' and 'after reaction' diagrams. Some students merely added up the number of species of each type in the 'before' and 'after' boxes with no recognition that one of the species was present in excess or of the need to simplify the coefficients in the equation. As well, many students disregarded the different meanings of formula subscripts and equation coefficients.

It seems apparent that many students lack a conceptual understanding of the submicroscopic particulate nature of matter and the changes represented by chemical equations. In addition, Andersson (1986) and Ben-Zvi et al (1987) identified students who held a 'static' rather than 'dynamic' understanding of chemical reactions. Such students failed to visualise chemical reactions as dynamic processes in which particles/molecules react to produce new particles/molecules by rearrangement of the atoms through breaking bonds and forming new bonds.

Clearly, many students' ability to balance and understand chemical equations is limited by their lack of understanding of the submicroscopic particulate nature of matter and their inability to visualise the dynamic nature of chemical reactions. This inability to visualise reactions probably also limits students' success in solving stoichiometric calculations, particularly where these are of a non-routine nature.

The difficulties students experience because of the abstract, unobservable, particulate basis of chemistry was previously described within the Piagetian epistemological framework (Herron, 1978) and several authors (Garnett, Tobin & Swingler, 1985; Gabel & Sherwood, 1980; Herron, 1978) advocated the use of concrete models to help students better understand the nature of matter. Modern multimedia technology has considerable potential to provide students with simulations of the submicroscopic/particulate nature of matter in its various states and the processes underlying physical and chemical change.

Chemistry at the macroscopic, submicroscopic and symbolic levels

Johnstone(1991) has proposed that chemistry is taught at three levels. The macroscopic level is sensory and deals with tangible and visible phenomena (eg. salt dissolving in water). The submicroscopic level provides explanations at a particulate level (eg. disruption of the ionic lattice and ions, surrounded by water molecules, moving into solution). The symbolic level represents processes in terms of formulas and equations (eg. $NaCl(s) + H_2O(l) \longrightarrow Na^+(aq) + Cl^-(aq)$). Johnstone believes that insufficient attention is given to understanding chemistry at the submicroscopic level and has pointed out the difficulty for students when teachers move quickly between these different levels. Perhaps it would be useful to students to point out these different ways of knowing chemistry, and to clearly identify for students which level of thinking is being used at any particular time. From the research evidence available at this stage, it appears that students have most difficulty in dealing with the submicroscopic which is, of course, outside their experience and can only be made accessible to students through the use of models, analogies or computer graphics.

Computer based instructional materials

Major difficulties for students of chemistry are the abstract, unobservable particulate basis of chemistry and the manner in which practising chemists and chemical educators move between the macroscopic, submicroscopic and symbolic representations of chemical substances and processes. These difficulties represent significant problems for chemistry educators but modern audiovisual technologies including the use of computer graphics provide exciting opportunities to present students with acceptable concrete representations of the particulate basis of chemical structure and behaviour.

Several studies (Hameed, Hackling & Garnett, 1993; Zietsman & Hewson, 1986) have indicated that it is possible to develop computer based instructional materials based on a conceptual change pedagogy which facilitate improved student understanding. This instruction is most likely to be successful when it provides visual concrete representations of unobservable processes and events, and causes students to reflect on their present conceptions.

Interactive multimedia describes an instructional technology with a number of critical attributes (Jonassen, 1988). In particular this medium includes opportunities for high levels of student engagement, the use of multiple media forms to represent information, and contextual feedback in response to student input. In addition IMM technologies are able to provide learning environments which are self-paced, able to cater for individual differences among students, learner centred, flexible in terms of time and place of delivery, and potentially offer a collaborative learning environment.

Interactive multimedia materials are eminently suited to the simulation of chemical processes using dynamic graphical representations of molecular interactions.

Tasker, Chia, Bucat and Sleet (1996) have reported recently on the VisChem Project which has developed molecular animations of a range of chemical processes aimed at improving students' understanding of the submicroscopic/molecular basis of these processes.

Description of the Project

This project developed an across-platform interactive multimedia package designed to help beginning students to understand the particulate basis of chemical reactions, their symbolic representation as chemical equations and to apply this understanding when balancing equations and solving simple problems based on equations.

The materials were designed to expose students to the three levels of chemical knowledge described previously, ie. the macroscopic, submicroscopic and symbolic levels, and provide an understanding of the particulate basis of chemical reactions. As well it was intended that the program provide opportunities for students to learn and practise the steps associated with balancing chemical equations. Finally the program aimed to develop students' skills in interpreting chemical equations at a quantitative level including an understanding of the concept of limiting reagent.

The project has developed three discrete modules that introduce students to chemical equations and develop skills in balancing equations and their interpretation. The materials are designed for use in lecture, tutorial or self-instructional modes. Two modules deal separately with 'molecular' and 'ionic' equations . A third module provides students with practice in the interpretation of equations.

Modules 1 and 2 both include instruction relating to eight chemical reactions. For each of these eight reactions students can:

1. View a video demonstration transformed into computer images. These images were intended to show students the actual appearance of a reaction when it occurs in real life. The purpose of this macroscopic view was to provide a link between the real world and the submicroscopic/particulate models chemists use to interpret chemical reactions;
2. View a simulation of the reaction at a particulate level; these animations use dynamic graphics that illustrate the behaviour of atoms and molecules and the transformations they undergo in chemical

reactions. The animations were designed to represent, at a particulate level, the processes that occur during chemical reactions using information that is available about these processes. In some examples where these processes are very complex, the process animations were simplified;

3. Write a balanced chemical equation. Equations are used to represent chemical reactions at a symbolic level. Students are provided with a particular approach to the balancing of equations which enables them to scaffold their knowledge. In this interactive program students are provided with a word equation and are asked to enter the formulas of each of the substances involved. Feedback is provided in relation to the chemical formulas written and also on the coefficients used to balance the equations. An option allows students to enter the physical states of all the substances involved.

Practice sets of twenty additional reactions are provided with both these modules to give students further practice in writing balanced chemical equations.

In Module 3 students develop their understanding of what chemical equations represent and their skills in interpreting equations. They are asked to interpret equations by drawing "before" and "after" diagrams to represent what occurs in a chemical reaction; do simple calculations to develop an understanding of the meaning of coefficients in chemical equations; and write equations to represent reactions illustrated by "before" and "after" diagrams. The concept of limiting reagent is introduced in some sections of this module.

Features of the IMM Materials

Use of Illustrations and Dynamic Graphics

The program was designed to make extensive use of video illustrations and animations using dynamic graphics. Levin (1981) has described the advantages of using these images in learning materials. From a cognitive perspective, graphics have been found to help learners focus their attention on explanative information and to aid them in organising information into useful mental models (Mayer, 1989).

Learner Interactivity and Engagement

The program was planned with a number of opportunities for learner interactivity and engagement. Planning of the interactions was guided by constructivist principles that place high levels of importance on learner activity in any instructional setting (Reeves, 1993). Constructivist epistemologies value learner-centred activities that facilitate personal involvement in creating and framing knowledge construction through students' cognitive activities (Lebow, 1993; Reeves, 1993). In multimedia environments, interactivity that leads to high levels of cognitive engagement appears to be an important aspect in achieving this.

Feedback

Feedback routines were carefully planned to encourage reflection among learners and to anticipate learning difficulties based on learner responses. A decision was taken to include oral feedback in certain parts of the program in place of conventional textual feedback. Cognitive load theory (Sweller, 1988) reasons that when viewing computer feedback in several forms, for example, animations and textual descriptions, the tasks create split attention with the learner attending to two discrete information sources. The theory argues that one of the sources can be neglected and the learning becomes inefficient and ineffective. The use of oral and visual feedback can reduce the split attention and lead to enhance learning outcomes.

Interface Design

In most CBL packages learner control is a key element of the instructional design and high levels of learner control are usually considered a positive attribute associated with increased learner motivation and achievement gains. The user interface for this program provided for higher rather than reduced levels of learner control. We planned to exert some instructional influence over naive users through implementation strategies that included a level of instructor support and scaffolding. The program content was organised in an hierarchical fashion which reflected a recommended instructional sequence but which placed little constraint on users' instructional choices. An aspect of the implementation of this project will be to investigate and explore implementation strategies that can be linked to high levels of learner achievement.

Conclusion

This IMM package was designed to improve students' understanding of the particulate/molecular basis of chemical reactions, and their ability to interpret chemical equations and solve problems based on equations. The provision of concrete representations of unobservable entities and processes, and the use of an interactive approach with associated feedback should facilitate students' achievement of scientifically acceptable conceptions of chemical equations and their application.

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Anyone Can Teach Science: An Old Argument Revisited

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Abstract

Discussion between those who believe that, with some curricular support, any good teacher can teach science and those who believe that it requires a specialist has been prolonged, sometimes heated and usually inconclusive. This paper reflectively explores interpretive results from a study in which the author team-taught with a group of five non-specialist science teachers who were teaching science to Year 7 and 8 students for the first time. The results of the study will probably not settle the argument, however they may reconstruct it in more productive ways. The research also offers intriguing possibilities for ways to support non-specialist teachers in teaching science.

Introduction

When teachers, teacher educators and the general public talk about just what qualifications are needed for teaching science, and what characterises good science teachers, subject knowledge is always one important facet. Certainly we hear anecdotes of teachers who 'knew their stuff but couldn't teach', but much more disapprobation is reserved for teachers who 'didn't even know what they were talking about - I knew more than them'. In this discussion I want to explore just what it is about knowledge of science that is important to the activity of teaching science, in the context of my experience as a team teacher with a number of non-specialist science teachers. While Shulman's (1986) distinction between pedagogical knowledge, content knowledge and pedagogical content knowledge is one interesting approach to this question, I have chosen to construct the argument slightly differently for the case of science, because I believe that in science education what counts as both content knowledge and pedagogical content knowledge has recently undergone, and is still undergoing, a significant shift.

There are a large number of recent studies (a few examples include Atwood & Atwood, 1996; Ginns & Watters, 1995; McDevitt et. al., 1995; Shugart & Hounshell, 1995) in which the scientific knowledge and understandings of preservice and serving teachers have been examined - and usually found wanting.

Atwood & Atwood (1996) found that only one of forty-nine preservice primary teachers possessed what they defined as a scientific conception of what causes the seasons on each of their two tests, and that it was a different student on each occasion. They used two different instruments, a paper-and-pencil test and an explanation with models activity, to test the knowledge of the teacher education students, and suggested that the level of alternative conceptions held by these students would create serious difficulties for their own primary school students when this subject was taught, since not one of the 49 answered the question with a scientific conception for both tests. Shugart & Hounshell (1995) discovered a negative correlation between subject matter knowledge and being recruited or retained as a teacher - that is to say, those with greater degrees of subject matter knowledge tended to either not become teachers or to leave teaching for other professions.

The study of McDevitt et. al. (1995) is a little different, in that it seeks to compare the subject matter knowledge and understandings of preservice primary teachers in a model teacher education program with those in standard programs. McDevitt et. al. develop quite sophisticated instruments for measuring the richness and flexibility of students' constructs relating to the science ideas, rather than simply measuring their ability to recite scientific facts. They found that teachers in the model program did develop more thorough scientific understandings than their colleagues in standard teacher education programs.

Narratives of Classroom Experience

The following brief 'impressionistic tales' (Van Maanen, 1988) describe some of my experiences in working as a team teacher and science support person in five middle school classrooms in the northern suburbs of Perth. This teaching was conducted as part of a research project in the school, and I was present in the classrooms as a volunteer. My purpose for being present was to make rich observations of the life in classrooms, from a perspective balanced between that of a teacher and a university researcher. The teachers had agreed to let me into their classrooms to conduct my research because they perceived that my active role as a team teacher and collaborative planner would bring extra experience and expertise in the area of science, where they did not feel confident. In other words, I provided 520 hours of my time as a teacher and consultant to the school, and they provided a research site for me. Of the five teachers, three had been secondary school teachers with specialisations in areas other than science, including mathematics, English and Languages Other Than English. The other two were experienced primary school teachers.

I have changed all the teachers' names to protect their identities, and the characters presented in the following tales are composites bearing characteristics of more than one of the teachers. The tales do, I believe, capture something real about what happened in the classrooms, however they should not be taken as direct transcripts of actual incidents - they are my impressions, filtered through my own experience and knowledge, and constructed for my own purposes.

In acknowledging this, it is important that I disclose something of myself, in order that you, the reader, can make a judgement about the quality and usefulness of these impressions and ideas for your own purposes. I am a science teacher with four years experience in secondary school science classrooms in Victoria and New South Wales. I worked as a science lecturer and teacher educator in Papua New Guinea for two years, before coming to Perth in 1995. I have accumulated Bachelor of Education (Chemistry) and Master of Education degrees and am working toward my Ph.D. in science education. I felt that it was important to offer more to the school than I took away in my research, because I have an ethical commitment to caring for the participants (teachers and students). None of these professional facts define me, however: I'm also a Christian, but I am first and most and always a husband to Sue and a father to Cassie and Alex.

It should be noted that these tales go somewhat outside the notion of impressionistic tales described by Van Maanen (1988), in that as well as attempting to be rich portrayals of the surfaces of classroom events, they contain depictions of my own reflections and thoughts, as both the narrator of the tale and a character within it. These musings should also be considered as an integral part of the fictionalised tale, rather than a 'Gods-eye-view' commentary upon it.

The Water Atom

> "It's like the water atom", James is saying. He writes on the whiteboard 'H20'. "It has one hydrogen molecule and two oxygen molecules to make up a water atom." I'm sitting at the back of the room, the 'designated scientist' for the purposes of this Year 8 class, but James has the floor, he's the teacher. Should I correct him? And to what extent? Neither of us wants the students to take misinformation away from the lesson, but I don't want to undermine his authority either.
>
> The rain on the tin roof of the classroom gusts louder for a moment, and a squall blows it against the windows. The classroom is a drowsy island of warmth and over-used air, cut off from its surroundings by curtains of rain. I'd been struggling to stay awake in my chair at the back - our team-teaching is more often a two-handed performance from the front of the room, but today James wanted to take the lead, and I was pleased to let him.
>
> "Two hydrogens and one oxygen", I say, sitting up straighter, "the number relates to the letter it's after, not the letter it's before." At this stage, I choose not to correct the atoms/molecules terminology, or the use of subscripts - time enough for those ideas later.

This time, James accepts the correction and moves on - he's secure enough in his own area of expertise as a SOSE teacher that he's happy to be occasionally corrected in science. On other occasions, though, he's 'spat the dummy' and said "OK - you teach it!" That might be fine this year, but next year I won't be here to correct James, and he'll still be teaching science. With what kind of scientific information and understandings will his students leave Year 8?

True Facts

"Science is a way of finding out true facts about the world around us," says Christine one bright spring morning, "isn't it Mr Geelan?" I have all sorts of misgivings about this as a statement of the purpose of science - both from the perspective of philosophy of science and from concerns with social justice, equity and awareness of the value of other cultures. If it were me, I'd prefer to say something a little more equivocal, like 'science is a way of constructing ideas about the world that are useful for human purposes', and then go on to recognise the validity of some non-Western and non-mainstream perspectives on the world.

> As thirty-one faces turn toward me (no, actually about twenty-two - the rest are having whispered conversations about Melrose Place or adding a new layer of graffiti to their folders), I wonder - are these misgivings appropriate for sharing with this class, right now? I'm really not sure. Is studying the nature of science a legitimate part of Year 8 school science, or is it better to continue in the same old objectivist vein, then challenge it when the students are older and have more tolerance for ambiguity?
>
> The school has as two important facets of its mission statement the integration of curriculum across learning areas and inclusivity of gender and culture. The student body is very heterogenous - in Christine's class we have students from Bulgaria, China, Vietnam and Italy, and two Aboriginal students. There are even some female students! If we are to include the traditions and cultures of all these students, rather than just masculine Western culture, and if we are to integrate science meaningfully with other

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learning areas, showing its appropriate role in a mature understanding of the human world, then I think we DO have to address questions of the nature of science at Year 8.

Of course, I don't think all of this as Christine and the class await a response to her statement - these issues have been part of my thinking for a long time, and I really don't have a firm conclusion. What should I say?

Science Teaching and the Nature of Science

Many teachers and students, including James and Christine, would say that the problem with their knowledge of science - the deficit - is in the area of 'knowing scientific facts'. This kind of deficit is fairly readily remedied: there are CD-ROMs for that these days! James could go and check the composition of water, or ask a student to do it, and the slight misunderstanding would be cleared up.

Is it really that simple, though? Poincare said 'A scientist must organize. One makes a science with facts in the same way that one makes a house with stones; but an accumulation of facts is no more a science than a pile of stones is a house." This points at the idea that science is not simply a connection of unrelated facts, but an orderly, interconnected structure of understandings. Even if James and his students can recite the facts that 'a water molecule has the symbol H2O and contains two hydrogen atoms and one oxygen atom', if they do not have a rich web of connected understanding of the concepts of atoms, molecules and chemical bonding (at a level of detail appropriate for Year 8 students), and perhaps of the influence of microscopic structure on macroscopic properties, can they be said to know the relevant science?

This is one of the problems encountered when non-specialist teachers teach science - they may use as a teaching referent the notion of 'science as facts', rather than the notion of 'science as a network of understandings'. If teachers conceive of science as an unstructured collection of facts, they are likely to teach students similarly, perpetuating the misunderstanding. The point then, is that rather than a simple deficit of scientific facts - facts are easy to come by - one of the problems for non-specialist science teachers may be a naive or impoverished notion of the nature of science.

Christine's situation, however, is slightly more difficult. Although it is again concerned with the nature of science, and with a limited understanding of that idea, it is more difficult, because it falls in a more controversial area. Many scientists and philosophers of science would accept and affirm Christine's statement that science finds true facts about the world - others would not. Constructivist perspectives on epistemology and the nature of science are becoming increasingly influential in the field of science education, and constructivist science educators and philosophers would suggest a view of science more like the one I describe in the tale - science is a way of constructing ideas about the world that are useful for human purposes. What is perhaps required of Christine in her role as a science educator is a quite sophisticated understanding of these epistemological arguments about the truth value of scientific information and ideas, and beyond that, a knowledge of the developmental stages of her students against which to test the appropriateness of particular ideas for them, and beyond that a level of pedagogical content knowledge (Shulman, 1986) that will tell her what strategies are most effective in teaching those sophisticated understandings to students. In the tale I, a professional science educator with a science degree and considerable experience in science education, was not sure of the appropriate approach. How then can a teacher like Christine - excellent without doubt - be expected to make these judgements in the classroom with very limited knowledge of science and no education in the nature of science?

Conclusion

Based on my classroom experiences in the course of this study, it can be very difficult indeed for teachers without a good knowledge of science to be effective science teachers. Rather than a lack of knowledge of specific scientific facts, or even of processes and skills, the key problem is usually that such teachers lack a rich, flexible and viable understanding of science and the nature of science from within which to try to formatively understand the developing scientific understandings of their students. This means that they are unable to fulfil the challenging roles - as supporters and facilitators of students' learning - demanded of them by current developments in education. For this reason I would suggest that the teaching of science, particularly in the secondary school, by teachers without a background in science is generally not as effective as it could and should be.

One question requires further research: is it possible for prospective science teachers to be supported and encouraged in developing this type of rich understanding of science through relatively short professional development courses, incorporating aspects of the history and philosophy of science, as well as thorough and reflective study in a few science 'content' areas? The research of McDevitt et. al. (1995) suggests that this may be possible. Or is only very prolonged and significant study of science such as an undergraduate degree sufficient for this purpose? (And conversely, does a science degree always lead to such an understanding?) An answer to this compound question offers significant potential for affecting the future direction of science teacher education.

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Prior Knowledge, Prior Conceptions, Prior Constructs: What Do Constructivists Really Mean, And Are They Practising What They Preach?

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Abstract

Papers and presentations within the broad constructivist/conceptual change axis within science education usually include some commitment to the idea that learning must build on students' existing mental structures. In practice, however, for some this translates as 'previously learned school facts', for others as 'misconceptions' to be swept away, while still others develop complex instruments and strategies for exploring students' sense-making schemes. From a perspective informed by both Kelly's 'personal construct psychology' and Glasersfeld's 'radical constructivism' I suggest that it is simply impossible for a teacher to meaningfully construe a student's construction processes, and that such efforts are misguided. Instead of attempting to discover what students know and then build on those foundations, I suggest that the teaching/learning/research process must be re-imagined as 'collaborative social learning' if constructivism is to be meaningful in science education.

Introduction

Constructivist perspectives on teaching and learning (as opposed to, or at least derived from, constructivist epistemological perspectives) generally affirm two general principles:

1. Knowledge is actively constructed by learners, rather than transmitted by teachers.
2. Such knowledge is constructed on the 'foundations' of students' existing knowledge, not on a 'blank slate'.

This discussion is concerned with the second of these principles - I wish to explore what is meant by 'existing knowledge', and the wide variety of near-synonyms used within the various tribes of constructivism (Geelan, in press). Such terms include the 'prior conceptions', 'misconceptions' and 'alternative conceptions' of the conceptual change paradigm (Posner et al., 1982) and Vygotsky's (1978) 'spontaneous knowledge'.

I want to suggest that, while these perspectives have been valuable in taking the discussion in science education beyond behaviourist and transmissivist models which minimise the role and importance of the learner in learning, they are ultimately both philosophically untenable and educationally unfruitful. Rather than expending energy and time on attempting to understand students' understandings from the 'outside', I suggest that we're all in life, and school, together. As I have said elsewhere:

> If constructivism is to mean anything, it must mean that the theorist is irrevocably involved in life, in social interaction, in learning - in the very things the theory purports to explain. This being so, there is no meta-theoretical perspective, no 'outside' from which to understand the activities of teaching, learning and research. They must be understood from 'inside' through social relationships which define both the mode and the content of our discourse. (Geelan, in press).

Prior What?

This issue has been raised again for me recently as I worked as a tutor for external postgraduate students in a science education course. One of the assignments for a curriculum unit asked students to develop a unit of study for their secondary school science students, using constructivist perspectives on teaching and learning. In an alarming number of these assignments I read sentences like "in order to determine the existing knowledge of the students, I had them do a paper-and-pencil test". In other words, for these teachers, 'existing knowledge' meant 'already memorised school facts', and to build on existing knowledge meant to add to this collection of school science facts. This may be due to limited conceptions of the nature of science and school science (Geelan, 1996), or to a poor understanding of constructivist perspectives, however it is a very common 'misconception' (to turn the terminology of the field in on itself) of new converts to constructivism.

Certainly the idea that 'prior knowledge' means that selection of 'school facts' already written on the blank slate is not the view of the authors of seminal works in the field. Posner, Strike, Hewson and Gertzog (1982) speak of 'interpretive frameworks', Piaget (1972) of 'schemes', Kelly (1955) of 'construct systems' and Glasersfeld (1989) of 'conceptual structures'. By these they mean complex, inter-related, well elaborated networks of constructs and understandings which serve an adaptive function by allowing learners to explain their past experiences and predict their future experiences. Piaget (1972) introduces the terms 'assimilation' - placing new experiences within the existing sense-making schemes - and 'accommodation' - adapting the schemes themselves to explain anomalous experiences - and describes their dynamic interplay in learning.

Constructivist perspectives on teaching and learning have posited the existence of students' sense-making schemes and suggested that it is educationally necessary for teachers to take them into account in teaching, usually including some attempt to measure the students' existing conceptions. There remains the difficult question - assuming that it is desirable for teachers to somehow measure the existing knowledge or prior conceptions of their students, is it possible for them to do so? (This leaves aside the equally difficult questions of whether it is possible for a single teacher to understand richly the sense-making schemes of 30 students, and of what kinds of tests or instruments might allow such teacher understanding to be developed within the limited time available.)

Construing Others' Constructs

George Kelly's (1955) 'personal construct psychology' is one important theoretical plank of personal constructivist perspectives on teaching and learning. The 'fundamental postulate' of personal construct theory is that "A person's processes are psychologically channelized by the way in which he anticipates events" (quoted in Bannister & Fransella, 1971). This postulate is supported and elaborated in a series of eleven corollaries. Taken together, the formal content of personal construct theory suggests that human beings develop complex, hierarchical, dynamic systems of constructs, based on the replication of experiences, with which to anticipate future experience. This corresponds closely to other personal constructivist perspectives such as those of Piaget (1972).

The corollary which is of most interest in the present discussion is the 'sociality corollary', which states: "To the extent that one person construes the construction processes of another he may play a role in a social process involving the other person" (Bannister & Fransella, 1971). This reminds us that, from a constructivist perspective, we have no *direct* access to the construct system of another - when we attempt to understand their understandings, we are ourselves involved in a construction process, one of construing their constructions. Steier (1995) refers to constructivist perspectives which ignore this idea as 'naive constructivism' - the belief that it is possible for us as teachers or researchers to stand back and objectively observe others enmeshed in the processes of construction. Instead, Steier claims, we must recognise that we are ourselves enmeshed, that "the idea that 'worlds are constructed' applies to US as well" (1995, p 13).

If we combine personal construct psychology's 'sociality corollary' with radical constructivism's (Glasersfeld, 1989) assertion that knowledge performs only an adaptive function, and tells us nothing about ontological reality, we come up against problems in deciding what status to assign to our knowledge of our students' knowledge. Glasersfeld has addressed this question directly - he states:

> ...introducing the notion of social interaction raises a problem for constructivists. If what a cognizing subject knows cannot be anything but what that subject has constructed, it is clear that, from the constructivist perspective, the others with whom the subject may interact socially cannot be posited as an ontological given (1989, p 126).

Glasersfeld goes on to develop a constructivist perspective on social interaction, however this never carries us any closer to a direct understanding of another's constructs - we must always construe them, based in our own experiential reality, and often on flimsy evidence. (People may lie, or be unable to clearly communicate their own constructions; cultural differences may lead us to misconstrue the signals of another.)

Does this scepticism about the possibility of understanding another's understandings in any final way lead to despair about the possibility of teaching in ways that take student's existing schemes into account? By no means! Rather than retreating from constructivism into perspectives which take the learner's sense-making schemes less seriously, we need to advance into perspectives which take students', teachers' and researchers' collective construction processes more seriously.

Reflexivity

Frederick Steier (1995) discusses the idea of 'reflexivity' from a perspective that he characterises as 'ecological constructionism'. Here he describes unreflective constructivism and constructionism:

> ...there have been many who have adopted a constructionist label to what is still defined by objectivist enquiry. Here we find those who take, as an object of study, other persons' constructions of reality as something to be understood in an objective manner, somehow apart from the researchers' own tools and methods. (Steier, 1995, p 70)

Steier emphasises that it is impossible to gain direct and unfiltered access to the construction processes of another - as suggested in the preceding section from both a personal construct psychology and a radical constructivist perspective, we are always one level of construction away. Rather than finding this daunting or worrying, however, Steier celebrates the circularity and reflexivity of constructionist research and teaching by calling those with whom he is involved in research 'reciprocators', rather than 'subjects' or 'informants', in order to emphasise the collaborative nature of such work. He notes that answers to interview or test questions are given *to someone* - the answerer construes the person and expectations of the questioner, and answers appropriately. Thus, the person of the teacher or researcher cannot disappear from the research - if the research report does not identify the researcher, then something essential about the data is lost. Similarly, when a teacher attempts to construe the construction processes (or prior conceptions, or sense-making schemes) of a student, the student is construing the teacher right back, and the answers received will reflect this. The student's construct system is not inert - by analogy with quantum mechanics, observing it changes it. This further distances the possibility of teachers usefully measuring and describing students' existing knowledge.

Collaborative Social Learning

What is the solution to this apparent conundrum? We can only abandon our 'objective' pose on the side of the pool of life, take off our suits and ties and jump in - we were always immersed in life anyway; our pose of dryness was a con!

Regarding the merging that occurs between the various social activities and interactions of research, teaching and learning if a concern for reflexivity is taken seriously, Steier says:

> Thus we must recognise that...we, as researcher, act as teachers. In addition...our reciprocators act as teachers... Understanding this might, in turn, allow us to learn what we already know, or to be surprised. Constructionist research programs that take issues of reflexivity seriously necessarily become programs of collaborative learning. (Steier, 1995, p. 84)

What form might such 'collaborative social learning' take in the classroom? Jardine and Clandinin's (1987) conception of 'teaching as story-telling' holds out some entrancing possibilities:

> The meaning, sense and significance of features of the child's curriculum emerge out of the child's sense of the on-going narrative of the classroom, a shared narrative between teacher and child... The meaning emerges out of the living context of the class, the living history of the class. Teaching as story-telling is not a matter of the teacher inventing a story ... as if the teacher is able to understand alone what this can mean and can decide how it might become topical in a class. (Jardine & Clandinin, 1987, p 477)

In this image we see an organic, emergent, dialogical process of mutual meaning-construction and rich interaction replacing a monological tale, told by the teacher alone. Students and teacher together explore the world and create an on-going narrative, an on-going living tale of 'life in our class'. In Jardine and Clandinin's image of teaching and learning, there is no question of the teacher stepping back and 'objectively' looking at the students, measuring their prior conceptions and tailoring teaching to them. Instead, I am led to return to the term 'organic' to describe the process of instant, moment-by-moment evocation and response and feedback that characterises this type of teaching. Rather than abstracting students' knowledge-making schemes from the contexts that give them meaning, the teacher seeks to interact with, understand intuitively and respond appropriately to the students on a human level.

Conclusion

Attempting to measure and understand another's construction processes in any final, objective sense is, in my opinion, neither philosophically tenable (particularly if our constructivism incorporates a concern for reflexivity) nor educationally fruitful. My suggestion, then, is that teaching, learning and research in education instead be re-imagined as 'collaborative social learning', in which students, teachers and researchers recognise in one another other human beings with whom they can play, live and learn. In the process, the learners teach and the teachers learn, and new knowledge is generated through rich social interactions.

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Progression in Learning How to Work Scientifically

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Abstract

Trailing of the *Working Scientifically* strand of student outcome statements in Western Australia has focussed on developing strategies for implementing and evaluating open investigation work in primary and secondary school science so that data could be collected to clarify and validate the progression described in the student outcome statements. Out of this work has emerged the view that progression in learning can be facilitated by matching the degree of openness and complexity of investigation tasks to the experience and skills of the student, providing scaffolding to support student decision making, and by using teacher formative assessment and student self-assessment set within the developmental framework of the student outcome statements.

Introduction

The National Science Statement (Australian Education Council, 1994a) and the Key Competencies Report (Mayer, 1992) have placed a high priority on the development of investigation and problem-solving skills in Australian schools. The student outcome statements of the *Working Scientifically* strand of the National Profile (Australian Education Council, 1994b) describe progression in learning of science investigation skills through eight levels. Several authors have argued that scientific problem-solving skills can be developed through inquiry oriented or investigation style laboratory work that gives students opportunities to practise the skills of problem analysis, planning experiments, collecting, organising and interpreting results (Roth & Roychoudhury, 1993; Tamir & Lunetta, 1981; Tamir, 1989; Woolnough, 1991; Woolnough & Allsop, 1985). There is a need to increase the opportunities within the secondary science curriculum for students to work on open investigation tasks so that they can develop science investigation and problem solving skills (Hackling & Garnett, 1995; Staer, Goodrum & Hackling, 1995). We need to help students make the transition from passive followers of recipe style laboratory worksheets to become autonomous decision makers on problem solving investigation tasks. This paper describes the nature of open investigations and outlines some approaches to facilitating students' progression in learning science investigation skills. The recommendations made in this paper are based on the experiences of trialing the *Working Scientifically* strand in Western Australian schools in 1995 and 1996.

What is an Investigation?

Investigations are activities in which students take the initiative in finding answers to problems (Jones, Simon, Fairbrother, Watson & Black, 1992). The problems require some kind of investigation in order to generate information which will give answers. Garnett, Garnett and Hackling (1995) describe a science investigation as "a scientific problem which requires the student to plan a course of action, carry out the activity and collect the necessary data, organise and interpret the data, and reach a conclusion which is communicated in some form" (p. 27). The planning component and the problem solving nature of the task distinguish investigations from other types of laboratory work.

Many would now argue that the student needs to be involved in selecting the problem or variables to be investigated, and the problem should be embedded in a context that is familiar to the student for the learning experience to be meaningful and represent authentic science (Woolnough, 1994). Student choice enhances ownership, motivation and persistence in the face of difficulties.

It is convenient to identify different phases in investigations such as a beginning or planning phase, a doing phase, and a concluding phase. The *Working Scientifically* strand in the Western Australian science curriculum (Education Department of Western Australia, 1994) contains four sub-strands; Planning investigations, Conducting investigations, Processing data, and Evaluating findings. In practice these phases may not take place in the strict order of, say, Planning - Conducting - Processing - Evaluating because half way through Conducting it may be realised that some more planning is needed and therefore a more recursive model (see Figure 1) may more accurately represent the investigation process.

A model of science investigation processes

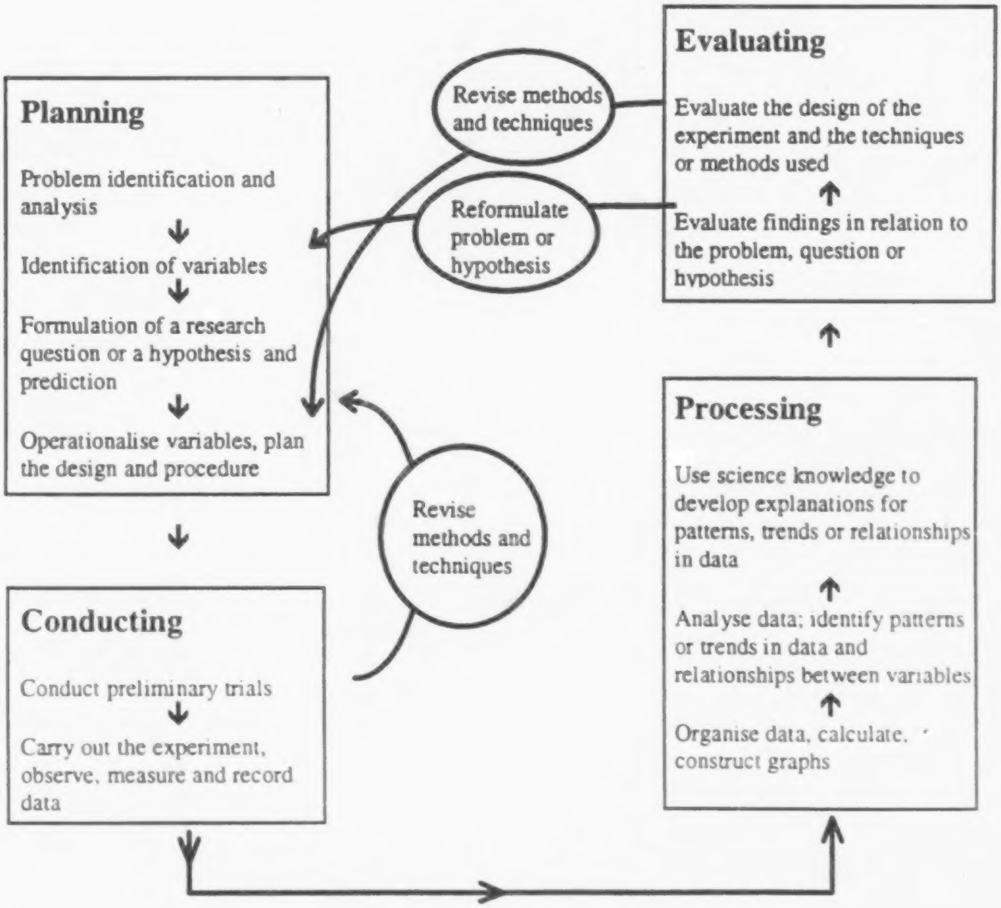
Planning
Problem identification and analysis
Identification of variables
Formulation of a research question or a hypothesis and prediction
Operationalise variables, plan the design and procedure
Conducting
Conduct preliminary trials
Carry out the experiment, observe, measure and record data
Processing
Use science knowledge to develop explanations for patterns, trends or relationships in data
Analyse data; identify patterns or trends in data and relationships between variables
Organise data, calculate, construct graphs
Evaluating
Evaluate the design of the experiment and the techniques or methods used
Evaluate findings in relation to the problem, question or hypothesis
Revise methods and techniques
Reformulate problem or hypothesis
Revise methods and techniques

Figure 1. A model of science investigation processes (Hackling & Fairbrother, 1996)

Facilitating Progression in Learning How to Work Scientifically

Progression in learning to work scientifically involves changes to the roles of the teacher and students, and changes to the nature of the investigation tasks. Some aspects of progression are outlined in Figure 2.

From	To
The Teacher	
Directing activities	Allowing autonomous working
The Students	
Following instructions	Being an autonomous decision maker
Being uncritical	Using creativity, judgement and critical thinking
Using simple procedures	Devising and using complete procedures and techniques
The Investigation	
Informal exploration	Systematic investigation
Simple information	Complex information
Everyday context	Scientific context (derived from the science being taught.)
Qualitative data	Qualitative and quantitative data
Discrete variables and data	Continuous variables and data

Figure 2. Some aspects of progression in working scientifically

It is argues that progression will be facilitated by:

- Matching the openness and complexity of the tasks to the experience and skills of the student.
- Providing appropriate scaffolding to support student decision-making.
- Student self-assessment and teacher formative assessment linked to outcome statements.

Matching the Openness and Complexity of the Tasks to the Experience and Skills of the Student

There are a number of significant task and context variables that influence the difficulty of the investigation. The extent to which the problem statement specifies and operationalises the variables determines the openness of the task. Openness can be increased for more experienced students. The nature of the variables and data (discrete – continuous, qualitative – quantitative), the procedural complexity, and the sophistication of the conceptual context also have to be matched to the readiness of the learners. The uncertain leading edge of students progress must be viewed through a 'window' that includes those things the students have learned and in which they have confidence, those competencies with which students are currently grappling, and the things that are yet to be encountered. The difference between what the student can do independently and autonomously, and that which can be accomplished given the support of peers and the teacher has been described as the zone of proximal development or ZPD (Vygotsky, 1978). The openness and complexity of tasks need to be matched with the student's window of progress so that the task is slightly in front of the leading edge of developing competence and is therefore challenging without being daunting. This will allow students to work within their ZPD and given appropriate scaffolding they should make good progress.

Providing Appropriate Scaffolding to Support Student Decision-making

To support students as they move from dependence on recipe-style worksheets towards being autonomous decision-makers they need scaffolding (Vygotsky, 1978) to structure their work. Our experience has been that planning and report sheets that list a sequence of questions (e.g. What are you going to investigate? What do you think will happen? Why will that happen? What are you going to do? What will you need? How will you make it a fair test? etc.) are very effective in structuring a sequence of decision-making steps for the students (Hackling, 1995). Planning the design of the experiment and planning for control of variables are complex tasks which may require additional scaffolding for inexperienced students. This can be provided in the form of a variables table (see Figure 3) and teacher modelling of its use.

Research question: How does the amount of light affect the growth of seedlings?

What I will keep the same	What I will change	What I will measure
type of seeds	*the amount of light:*	*the height of the seedling*
type of soil	*dark*	
amount of water	*partial shade*	
amount of fertiliser	*full sun*	
size of container		
planting depth of seeds		
Controlled variables	Independent variable	Dependent variable

Figure 3. An example of a variables table (Hackling & Fairbrother, 1996)

Inexperienced students may need teacher intervention to help them work through a problematic aspect of their investigation. The use of open questions to scaffold students' analysis and resolution of the problem can be quite powerful where the teacher structures the students' thinking through the problem rather than providing a ready-made solution. The learning of these complex craft skills of science can be facilitated by the teacher adopting teaching strategies consistent with a cognitive apprenticeship model of instruction (Garnett & Hackling, 1996), such as modelling, scaffolding, coaching, providing opportunities for students to explain, discuss and compare ideas and strategies, and the fading of support as competence develops (Hennessy, 1993).

Student Self-assessment and Teacher Formative Assessment Linked to Outcome Statements

To facilitate progression students need to know the assessment criteria, what they are doing well, what they are doing poorly, and what they need to do better or differently to make progress (Black, 1993; Torrance, 1993). A profile of learning outcome statements that describe progression in learning can provide a framework for student self-evaluation and teacher formative evaluation. Such evaluations can locate the student on the profile and help identify what must be done for progress to be made. Discussions between teacher and student about the student's performance in relation to the profile can help clarify the assessment criteria, what has been learned, and what must be learned next. Current assessment practices which are largely normative, summative and often atomistic and decontextualised will need to change significantly to being criterion or standards referenced, more formative, holistic and authentic if assessment is to make a greater contribution to student learning. Such significant changes to teaching practices will need to be supported with opportunities for teacher professional development.

Conclusions

The secondary science curriculum has to this point in time offered few opportunities for students to develop science investigation skills and become autonomous decision-makers on problem-solving investigation laboratory tasks. There is a need to increase the number of open investigation tasks in which students can plan and conduct their own investigations, analyse the data, and evaluate their own work. Teachers will need to plan carefully the sequence of investigation tasks that will match the skills and experience of their students, provide appropriate scaffolding to support students' developing investigation competencies, and use more student self-evaluation and teacher formative evaluation within a learning outcomes statements framework to facilitate progression in students' learning.

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Student Difficulties in Differentiating Heat and Temperature

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Introduction

The diverse intuitive views of the world that children bring to physics instruction is well documented in the science education literature (Driver et al., 1985, 1994; McDermott, 1993; Osborne & Freyberg, 1985) and an extensive body of theoretical and classroom research has been devoted to developing conceptual change teaching models that address these views (Duit et al., 1992; Hewson, 1981, 1982; Posner et al., 1982). Despite many successful students completing physics courses with some of their intuitive conceptions intact (Yager, 1991), progress in synthesising an effective model of conceptual change learning has been relatively slow. It was thought that discrepant event teaching would stimulate children to relinquish their ideas in favour of scientists' science; however, many students assimilate the 'new' science alongside their intuitive views, rote learn the science concepts for just the duration of the topic, or make little effort to reconcile obvious differences. Recent alternative perspectives on learning argue that conceptual change is often an incremental process (Duschl & Gitomer, 1991) that may be driven by a range of hot, irrational, social and motivational forces as well as cold, rational factors. Solomon (1987) claims that significant social factors influence classroom learning and knowledge construction, and social negotiation and group work are important ingredients in conceptual change.

Method and Summary of the Research

This research investigated five Year 11 physics students' conceptual development during an eight week study of heat and temperature at a new independent school. A qualitative case study was framed to describe the learning processes that favoured a change from intuitive student conceptions to the scientific view of heat and temperature. The author taught the class and was assisted in the teaching and research by a discussant and a colleague who provided theoretical and critical support. The class used the heat and temperature module in the *Physics by Inquiry* (Physics Education Group, 1988) curriculum materials which substantially satisfied the Secondary Education Authority's (1994) syllabus. The learning environment was restructured to allow the students to proceed at their own pace and to socially negotiate the learning outcomes in small group and whole class discussions. Converting the teacher-centred classroom into a student-centred one required the teacher to reconceptualise his role.

Three of the five students significantly restructured their conceptual understanding of heat and temperature in a scientific way. One unsuccessful student lacked the requisite cognitive ability and personal study skills, and another able but unsuccessful student lacked the necessary social skills for success in group work and independent learning. Four students progressively adopted scientifically precise language and the consistent verbal and written use of scientific terminology by three of the students supported the belief that they understood the concepts they described. Two students also reformed their thinking about science.

Analysis of pre-tests, initial discussions and early work showed that each student commenced each unit of study with naive, undifferentiated conceptions lacking a number of key concepts. Four students viewed heat and temperature as equivalent entities and this prevented them from solving simple everyday problems. During the initial discussions and activities, students developed an operational definition for temperature, and added the concepts of thermal interaction and thermal equilibrium to their conceptual framework. These ideas became anchoring conceptions that helped each student separate heat and temperature. Student investigation results provided information for use in concept substitution (Grayson, 1994) which led to the students to further differentiate heat from temperature and stimulated them to reconstruct their conceptual frameworks in a coherent way. As the course progressed, the three successful students consistently identified misuse of the concepts of heat and temperature by themselves and the two less successful students.

Thermal interactions were treated using proportional reasoning based upon the concept of heat capacities and temperature differences. Three students developed their own version of the standard heat calculations and in the final test, two quite different methods were used with equal success. Similarly, a series of concept maps showed that for each student, the number of concepts held increased with time; the detail and sophistication of the connections increased with time, and conceptual hierarchies emerged as the course drew to a close.

Theoretical Framework

Constructivist perspectives of knowledge development explain that rather than adopting the teacher's knowledge, students construct their own science conceptions. Students bring intuitive alternative conceptions to the classroom and they generate *synthetic models* as they try to make sense of their ideas and the teacher's instruction. Because alternative conceptions are firmly grounded in the student's everyday experiences, they are highly resistant to change (Osborne & Freyberg, 1985) and a range of conceptual change learning models have been framed which explain the tenacity of student conceptions (Carey, 1986; 1991). These authors argue that science learning consists of a mix of: knowledge accretion; assimilation, conceptual capture or weak knowledge restructuring; and accommodation, conceptual exchange or strong (radical) knowledge restructuring. Duschl and Gitomer (1991) claim that students continuously accrete knowledge so that over time their conceptions may gradually change from intuitive to scientific.

Concept substitution (Grayson, 1994) seemed an appropriate way to reform students' conceptions of heat and temperature because it involves probing each student's ideas to identify the scientifically acceptable aspects of the student's conception(s). Once the correct aspects of the student's understanding are identified and supported, scientifically correct terms and processes are substituted for the incorrect items. In this way, the students' correct ideas act as anchoring conceptions for the substituted ideas. This research also utilised the key elements of Ausubel's *meaningful learning* theory (Novak, 1984).

It was believed that Ausubel's theory of meaningful learning was particularly useful for interpreting changes in student conceptions that occur during constructivist learning episodes. "The central idea in Ausubel's theory is that of *meaningful learning*, which he defines as 'nonarbitrary, substantive, nonverbatim incorporation of new knowledge into cognitive structure'" (Novak, 1984, p. 608). Nonarbitrary incorporation of new knowledge means that the new knowledge is related to prior knowledge and that the learner makes conscious, deliberate efforts to harmonise the two. Ausubel recognised that each student's "cognitive structure is unique, and hence subsumption of new knowledge produces a cognitive *interaction product* that is dependent both on what concepts or misconceptions the learner already has and the material presented" (p. 608). Pretests and formative discussions that regularly revisit prior conceptions in light of current conceptions are very effective ways to monitor and consolidate student cognitive growth (Hashweh, 1986).

Progressive differentiation of concepts was particularly useful because most students treat heat and temperature as if they are equivalent; heat capacity and specific heat are transposed and heat transfer mechanisms are poorly differentiated. Not only must students differentiate these concepts, they must learn to reconcile each in an integrative way so that once they recognise how heat and temperature differ, they then need to understand how they are related. Students also need to develop the ability to use heat and temperature in a mutually constructive manner to make sense of thermal interactions: temperature differences explain why heat is lost and gained but there must be an understanding of the quantity of heat flowing and its effect, namely temperature or phase changes in the interacting objects. In Ausubel's scheme, students often engage in *superordinate learning*, that is, the generation new hierarchies and relationships between new and old knowledge. Concept maps are especially useful for identifying new hierarchies and new connections between propositions and concepts. Ausubel also proposed the use of *advance organisers*. This device, often an analogy, is more general and more inclusive than usual learning episodes and directs the student to new knowledge and may be "perceived by the learner to act as a cognitive bridge between what he or she already knows and what is to be learned" (Novak, 1984, p. 608).

Carey (1991) also found that children consistently fail to distinguish between entities like mass and density. She argued that students need to *differentiate* incompatible concepts (e.g., mass/density, heat/temperature - Wiser & Carey, 1983) and *coalesce* separate concepts that belong together (e.g., humans are animals). There seem to be strong similarities between Ausubel's and Carey's differentiations and between integrative reconciliation and coalescence; however, Ausubel's theory of meaningful learning is more comprehensive and seemed more useful in this study. The learning theories espoused by Posner et al., (1982), Novak (1984) and Duschl and Gitomer (1991) all emphasise the centrality of the student consciously examining his/her understandings and knowledge structures. These perspectives were believed to be important in this study. Because student alternative conceptions of heat and temperature are highly resistant to change, strategies which cause the students to repeatedly examine their beliefs offered the best opportunity to restructure student understanding. The theories of conceptual change and meaningful learning therefore offered the researchers a sound base for interpreting the learning events that occurred in the classroom.

HEAT PREDICTIONS

This is not a test. It will not affect your marks in any way. It will be most helpful to this study if you write as much as you can for each question.

NAME .... DATE ....

1. In your own words explain what you think heat is. Try to say where your ideas come from.
2. Suppose that you have two cubes of the same size, one made of wood and one made of metal. Both have been sitting in the room for some time. How do you think the temperature of the two cubes will compare? Explain your answer.
3. Suppose the oven is turned to 60° C and the following things are put in the oven and left there for a few hours: some flour, a bowl of water and some nails. After a few hours, how will the temperatures of the substances compare with each other? Explain your answer.
4. Suppose I have two bricks made from the same kind of clay, but one is large and the other is small. Suppose I put them both in an oven at 120° C for a few hours. At the end of a few hours how will the temperatures of the two bricks compare?

   [An oven containing the two bricks at 120° C was visible during this period.]
5. Suppose I have pot of boiling water on the stove. If I turn the stove up to a higher setting, what will happen to the temperature of the boiling water?

Figure 1. Heat pretest administered in lesson 1.

Results and Interpretations

The results are limited to a brief discussion of the conceptual development of one student who will be called Ken. Ken was chosen because his prior conceptions were clearly enunciated (verbally and in writing); he regularly volunteered his opinions and explained his views; and he did change his conceptions during the course of instruction.

During the heat and temperature pre-test (Figure 1), Ken described heat in typically unscientific terms: "Heat is a sort of energy which [is] created by burning things. ... Heat is easily conducted by some substance (i.e., metal) while not as easily conducted by others (i.e., non-metals). My ideas are just common knowledge." During the pre-test discussion with the teacher, Ken explained the behaviour of an iron and a wooden cube left in the sun in this way:

> the wood would stay just one temperature, the same temperature, the other one changes. Like if you put [the iron cube] in the sun it would get hot. ... I think it changes no matter what.

Further detail suggested that Ken reasoned teleologically because he states that objects react to thermal environmental changes based on the their macroscopic properties, function or use, and imposed events rather than in accordance with the principles of thermal interaction (Erickson & Tiberghien, 1985). Even when faced with sound contrary reasons from other students, Ken was adamantly satisfied with his explanation. Ken's thinking was guided by the iron cube feeling colder than the wood and by how he expects objects to respond when heated. For instance, he answered the third pre-test question saying that "the nails would be the hottest, then the water and least the flour. Because the nails trapped heat, the water would be boiling by then, but the flour is just about 60°C." He was quite sure that the water would boil in an oven at 60°C and verbally defended this position the following day. Ken knew that water boils at 100°C because he argued this concept when discussing Question 5. It is therefore intriguing why he insisted that the water would boil in an oven at only 60°C? The context may be important. When he said that the nails would be hotter, Ken may have thought the nail's exceeded 100°C. Everyday experience says that metal objects in ovens are very hot and will burn you, water boils or evaporates, and cereal type foods like flour are reasonably safe to handle. Ken may have ascribed greater importance to the oven ("is hot") rather than the temperature ("is 60°C"). If the oven's properties and function dominated, then this supports the claim of teleological reasoning and illustrates the degree to which prior knowledge interferes with science learning.

Teaching and Learning by Concept Substitution

During the pre-test and discussion, Ken displayed a rudimentary conception of heat and temperature and initially described temperature as a measure of the amount of heat in an object (i.e., extensive rather than intensive). One week later, the difference between heat and temperature was the subject of a lengthy discussion led by the discussant. The intervening activities asked the students to examine a variety of substances at different temperatures using their senses and thermometers to develop an operational definition for temperature. The transcript reveals that two of the students retained heat and temperature as equivalents and Ken's comments suggest that he was still unsure of the difference between the two terms, because he was unable to articulate a working definition of temperature. A review of the students' sensory experiences with different materials at different temperatures led to a unanimous conclusion that 'feel' is an unreliable determinant of temperature due to differing conductivities. Ken's concluding statement was that heat "is what causes the temperature to change." However, when asked to "go on", Ken was unable to extend this idea and disengaged from the conversation. At this juncture, concept substitution was employed by the discussant. Each student had volunteered his current understanding of heat and temperature and it was evident that these two concepts were still poorly differentiated (Novak, 1984). The focus for concept substitution was the question "what is heat?" and, "what is the importance of temperature in thermal interactions?" The discourse took this form:

Disc	Heat in fact, we can only talk about something being transferred, can't actually talk about an object as having heat, they have temperature and we can measure that with a thermometer but they don't have heat. Heat is something, we can't say exactly what it is, but it is something that is transferred. Now under what conditions will heat be transferred to another object?
John	When they have a different temperature.
Disc	And that process of transfer, we give that process a name, does anyone know what that name is?
Joe	Conduction.
Disc	That's certainly one of the ways that heat can be transferred, but more generally when two objects interact because they are at different temperatures, and they exchange heat, its general term is ...
Des	Radiation.
Disc	We call this a thermal interaction. Whenever heat is transferred between two objects that are at different temperatures, that process is called thermal interaction. Now if you have two objects in contact with each other at different temperatures, will that thermal interaction continue forever?
John	No, only till they get to an eventual temperature ... equilibrium.
Disc	They reach the same temperature or reach thermal equilibrium ...

The discussion continued with the discussant and the students restating and reinforcing their understanding of these ideas. The scientific definition of heat was developed as an *interaction product*

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between the students' ideas and the discussant's conception. Heat was progressively differentiated as energy that is "something being transferred" in contrast to temperature which was a measure of the intensity of the object's internal energy. Thermal interaction was introduced as a superordinate heading (Novak, 1984) for all forms of heat transfer, and when John introduced the equilibrium concept, the discussant was able to expand this into thermal equilibrium by building on the students' prior and current knowledge. Even though substantial scientific ideas emerged during this and previous discussions, the students did not adequately respond to the cue, "they exchange heat, its general term is?"; therefore, the discussant had to volunteer the concept "thermal interaction." The discussant conceptually substituted "thermal interaction" for all forms of heat transfer mentioned by the students.

A further examination of the last transcript then revealed a view of heat interaction that is static rather than dynamic. The conceptions of thermal interaction and thermal equilibrium still need to have the conflicting ideas of static and dynamic behaviour discussed, differentiated and reconciled. Only then will heat's dynamic nature be satisfactorily integrated into the students' conception of thermal interactions and equilibrium. The discussion returned to the pre-test question about the nails, water and flour left in the oven at 120^0. This became a context for applying the differentiated concepts of heat and temperature and the new concept, thermal interactions. Ken had previously asserted that the water would be boiling and the nails even hotter. He believed there could be some temperature differences between these materials even though he conceded that they should all be at the same temperature.

Ken's conception was changing, but it had not yet reached the scientific conception and he again expressed his uncertainty in the next exchange by ending a confused attempt at applying thermal equilibrium with "...I dunno ..." Later, however, Ken mastered the idea of thermal interaction and thermal equilibrium and for the 'method-of-mixtures' section, devised an elegant form of proportional reasoning for determining the final temperature of mixtures. Ken's approach to learning was characterised by greater intellectual honesty than any other student in the class. He consistently took risks by expressing his ideas irrespective of the status quo and he was unwilling to agree with either his peers or the teacher unless he could internalise the concept and fruitfully use it to solve his problems. Meaningful learning does not stop at the differentiation of, for example, heat and temperature; it pursues superordinate learning (here, thermal interactions and thermal equilibrium) and makes use of reconciliatory integrations where the conceptions are brought together to solve abstract or difficult problems. Teachers are often tempted to effect lesson closure once the desired concept emerges. Keeping the discussion 'open' is essential if real conceptual gains are to be made.

Summary

At the start of this eight week unit of study, Ken possessed a highly intuitive conception of heat and temperature. He visualised heat and temperature as similar entities and even though he believed that heat energy in an object can move into other objects, he lacked the systematic conceptions to explain heat transfers. Thermal interaction and thermal equilibrium concepts were nonexistent for he held that different objects can have different temperatures in the same environment. The use of pre-tests and carefully planned investigations, questions and discussions utilising concept substitution enabled Ken to address the incommensurable aspects of his knowledge. Ken progressively added scientific concepts like thermal interactions (involving heat gained = heat lost) and thermal equilibrium by conceptual capture. He concomitantly differentiated heat and temperature by constructing new conceptual hierarchies culminating in the integrative reconciliation of heat and temperature. Ken's mental model of thermal interactions was certainly intelligible and plausible and probably fruitful.

By the unit's conclusion, Ken viewed temperature as an intensive characteristic of objects and thermal interactions were described qualitatively and quantitatively. It is claimed that this student underwent a form of conceptual change in which the status of the scientific conception rose at the expense of his intuitive conceptions; but whether this change was a weak or radical restructuring is unclear. A sound argument can be made that Ken's conceptions evolved, that his conceptual changes were cumulative and piecemeal (Duschl & Gitomer, 1991) and that this required a dynamic social environment that provided consistent support for Ken and his peers as they struggled to accommodate new and counter-intuitive ideas.

Conclusions and Recommendations

Students have difficulty in differentiating concepts such as heat and temperature because their naive conceptions are robust and resistant to change. During traditional teaching, students appear to assimilate the scientific view of heat and temperature; however, this study shows that alternative student conceptions need to be revisited in a variety of contexts before student frameworks are adequately restructured. The significant factors in this process are *time*, *authentic problems*, *open-endedness* and a *socially supportive classroom*. It is likely that both the teacher and the students will be initially challenged by an open-ended student-centred learning environment like the one described in this paper. Nevertheless, this case study provides valuable insights into the variety of conceptual developments that take place in a group of students with differing intellectual and social backgrounds.

This case study also highlights the teaching and learning difficulties that accompany teaching for understanding rather than for content and quantitative problem solving. The observation that Ken's conceptual development was incremental and piecemeal supports Duschl and Gitomer's position (1991). Whenever learning is gradual and accretive, considerable time needs to be spent on progressively differentiating fundamental concepts so that students can build new conceptual hierarchies in which the fundamental concepts are integrated in a scientific way. Finally, this study re-emphasises the need for teachers to probe the understandings of their students before, repeatedly during, and at the close of instruction. To that end, this paper describes some of the methods that can be used by teachers to monitor the conceptual development of their students.

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What are the Qualities of a Good Explanation?

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What are Explanations?

Much has been written about the role of explanations in science (e.g., Achinstein, 1983; Hempel, 1966; Harre, 1988) with much less written about explanations in science teaching (Dagher & Cossman, 1992, Horwood, 1988; Martin, 1970). Horwood (1988) makes a distinction between 'explanation' and description' and illustrates by examples that, at the junior high school level at least, the two terms are often considered, at last by students, to be synonymous (Wong, 1993). At higher levels of secondary education, there is an expectation that the underlying mechanism of mitosis, for example, should be given in a question that asks for an explanation of mitosis. Further explanations involve 'explain how' and 'explain why' and the hearer or reader expects to learn about specific causes.

Suitable explanations in science are the essence of understanding any phenomena under investigation even though the research literature devotes little attention to teacher explanations (Shulman, 1986). Explanations can be presented from the logic of teaching (Smith & Meux, 1970), from a philosophy of science perspective (Hesse, 1970), or from an educational perspective (Martin, 1970; Ennis, 1986). However, in discussions about explanations, authors usually do not describe the nature of the science content being taught. Few studies have focused on the actual content, rather the content has been the convenient vehicle for examining teachers' explanations.

In this paper, we examine the overt features of science content knowledge and review the types of explanations available to teachers to explain this content. Very little research has been performed into the nature of explanatory frameworks, therefore there is little consolidated theory in this domain. In this paper therefore, a theoretical overview is developed that describes our research on the philosophy of explanation, the analysis of science content and of teachers' preferred explanations.

Properties of Content

White (1994) argues that the properties of the science content (see Figure 1) both limits and should influence the types of explanations used by teachers. For instance, abstract concepts like atoms and magnetism involve a high proportion of images and models that are most often presented as analogical models. Both the teacher's and the students' common experience, interests, preferences and culture interact in determining which explanations are most appropriate in a given situation. It may often be the case that multiple or mixed explanations are necessary to cater for the individual student differences present in any one class.

Openness to common experience
Presence of alternative models with explanatory power
Presence of common words
Demonstrable Versus Arbitrary
Extent of Links
Abstraction
Complexity
Mix of types of knowledge
Social Acceptance
Emotive Power

Figure 1. Properties of content that influence teaching procedures (From White, 1994, pages 256-262)

In brief, the terms in Figure 1 are described by White as follows:

Openness to Common Experience. Certain content like forces and motion, or light can be experienced by students and so interpretations are developed to account for instances that are often not in keeping with scientific explanations. How to explain content such as forces compared to solar system astronomy presents teachers with specific challenges.

Abstraction. Different content has different levels of abstraction such as displacement compared to acceleration. The more abstract the concept, the less likely that learners will have direct experience of it and so will not hold prior conceptions. How to take these differences into account when offering explanations also challenges for teachers.

Complexity. Some content comprises many components while others have few, for example, sound (many) compared to density (few). The need to explain the connections most likely requires different teaching approaches.

Presence of Alternative Models with Explanatory Power. One of the challenges for teachers is to know when best to use one model to explain a concept rather than another. Research suggests that the use of multiple models can be effective.

Presence of Common Words. Science teachers continually face the challenge of how to use common words such as 'animal', 'flower' or 'force' that have different meanings in science. How are these common words to be best used in teachers' explanations?

Mix of Types of Knowledge. An important property of content is the emphasis it puts on knowledge of different types such as propositions, images, episodes, and procedures. For example, explaining atomic structure presents many challenges. How do teachers decide when to use their preferred explanations?

Demonstrable Versus Arbitrary. Some content is organised in a demonstrable way such as flowering and non-flowering plants. Others are somewhat arbitrary such as physical and chemical change and are very difficult for the students to work out by demonstrations. How do teachers decide the best explanations in these situations?

Social Acceptance. Many topics of science such as creation and evolution, population control and consumption of fossil fuels are contentions. How are teachers to decide the explanations to offer and with what level of personal commitment?

Extent of Links. Content is often presented in science classes in a disconnected way. For example, the topic of cellular respiration is often presented at the beginning of a biology textbook but photosynthesis is presented much later without any reference to the earlier chapter. How should teachers decide which content needs to be connected and how should these relationships be explained to integrate these concepts?

Emotive Power. Different topics are more likely to arouse more interest than others. Are there different approaches for explaining the content if students' interests are different?

Analogical Explanations

Several of the above factors that enable teachers to create conditions in which students can learn by constructing their own knowledge are directly related to teachers' understanding of the science content. Related to teachers' content knowledge is their content-specific pedagogical knowledge which includes the use of those analogies that can effectively communicate concepts to students of particular backgrounds and prerequisite knowledge (Shulman, 1986). However, analogies are not used by science teachers as often as might be expected (Dagher & Cossman, 1992; Treagust, Duit, Joslin, Lindauer, 1992) in spite of the existence of useful analogies in the textbooks used in science classrooms. In addition, research suggests that when analogies are used in science classes they are frequently not presented in a manner which enhances their effectiveness. Recent research has shown that teachers can substantially help students in their understanding of concepts if analogies are presented in lessons in a systematic manner that is meaningful to the students (Glynn, 1991; Treagust, 1995). It seems most likely that the vast majority of science teachers have no formal training in the use of analogies and hence it is not surprising that analogies are not used in explanations as often as they could be.

A teacher's knowledge of science content in relation to the level of competence of his or her teaching has been largely ignored by researchers (Shulman, 1986). In our own work, however, we have observed the importance of subject matter knowledge when teachers introduce analogies to help students understand the phenomena under question. For example, the introduction of the car cooling system analogy for homeostasis and the fluid mosaic model to represent semipermeable membranes could not have been presented and used effectively in lessons with senior high school classes without very good content knowledge of the teachers concerned.

One of our current research programs is examining the contribution that analogies and models make to teachers' explanations and indicating in which ways the explanations are related to the nature of the science content. For example, explaining unfamiliar concepts by comparing them to familiar objects and processes is the very basis of analogy but an analogy will only bolster an explanatory framework if a genuine systematic similarity exists between the analog and the target.

Explanatory Frameworks

Explanations are usually framed in ways that reflect the style and individuality of the speaker or writer. The 'teacher as an artist' simile succinctly describes what may happen when a creative teacher crafts an elegant and concise explanation in a challenging situation. How do expert teachers draw creative word pictures that both appeal to and inform a diverse group like a class of students? Artists and craftsmen are distinguished by their styles and it is just as likely that expert teachers use an artistic style or creative format within which they logically develop their explanations, arguments and questions. Many educational writers call these structures "explanatory frameworks" but fail to explain what the term means. The idea of frameworks for conceptions (Toulmin, 1972) and explanations seems to be a popular post-modern notion that draws on schema theory for its justification. The "framework" metaphor evokes an image of a three-dimensional matrix where the nodes are schemata or conceptions and the interconnections could be the logical or aesthetic ribs upon which an argument or explanation is detailed and "fleshed-out."

A theory that is specifically scientific and which makes supportable predictions is an "explanatory framework" (Solomon, 1995, p. 16). Solomon reasons that a good explanation takes into account the audience and context and appears to be 'correct.' She gives this example.

> In science the explanation will not satisfy if it is, for example, in terms of human agency. When Bohr produced his famous explanation for the lines in the spectrum of hydrogen, which had been observed but not explained for half a century, it would not have done to attribute them to impurities in the hydrogen, nor to how the observer had carried out the experiments. A suitable explanation would need to start from Rutherford's sun-and-planet image of an atom which was familiar and acceptable to his scientific audience. This is just what Bohr did. Then he added to this his new concept of electrons in stationary orbits. The existence of spectral lines followed from the application of well-known principles of energy and frequency. The whole argument of the explanation fell comfortably within the context of contemporary physics. (p. 16)

When crafting explanations, scientists, teachers and students are not free to use just any sort of explanation, acceptable explanations need to agree with the scientific consensus on the subject. A second important feature of an explanatory framework is its holistic agreement. Bohr satisfied both of these conditions by applying his new ideas to the previous scientific consensus and out of it, synthesised a powerful new theory.

Solomon also points out that metaphors, analogies and models are important components of explanatory frameworks. Explaining unfamiliar concepts by comparing them to familiar objects and processes is the very basis of analogy but an analogy will only bolster an explanatory framework if a genuine systematic similarity exists between the analog and the target. Many scientists have supported their explanations by analogy (Lorenz, 1974; Oppenheimer, 1955) and other scientists (e.g., Kepler, Van't Hoff, Pasteur) have even used analogy as a source of scientific discovery. Thus, science often uses models as analogies, indeed, it is often difficult to differentiate between an analogy and a model in science. This is why this paper chooses to use the term, analogical model for the analogies and models that are used in chemistry.

Factors Which Influence Explanations

Broadly speaking, we are concerned about teachers' explanations that impart knowledge and promote student understanding. We believe that how these explanations can be analysed in a meaningful manner depends, to a large extent, on the theoretical analysis of the content of the science. In this regard, it is our contention that an investigation into the relationship between the content being taught by teachers and the manner in which they go about explaining it can have useful outcomes for improving classroom practice and students' learning.

When experienced teachers decide to explain difficult concepts in a particular way, they are usually influenced by a variety of factors related to the content, the teacher and the students. Some of these factors are listed in Figure 2. The teacher and student factors are recognised as being very important for learning and for successful teaching, but in this paper we do not address all of them but rather attempt to examine the content factors in terms of the explanations preferred by science teachers.

In an interesting discussion on the process of developing science content in constructivist teaching, Carr et al. (1994) show how teachers can use constructivist principles to enable them to explore the nature of the science content with their students. Questions debated are: 1) Does nature contain a definition of the concept which can be uncovered through appropriate experiences?, 2) How does a scientist develop a statement of a concept?, 3) Is there a single explanation for a phenomenon which teachers should aim for?, 4) Can science always provide an answer to a question?, and 5) When a 'better' explanation is proposed, how do scientists decide to accept it? (p. 151).

Answers to these questions illustrate the complexity of the task at hand in providing explanations in the science classroom. Also, the questions point out the difficult burden placed on science teachers because school science can only be provisional knowledge leading towards the scientist's construct. In most cases the scientist's constructs are inaccessible to students - the properties described earlier by White give some indications of what these might be and why they are they are inaccessible - so transitional concepts should be addressed in a comprehensible manner.

In responding to question 3, Carr et al. proposed that the level of explanation depends on the purpose of the exploration and the background of the students for whom the explanation is provided. They also emphasised that it is "inappropriate for classroom interactions to convey the impression that here is a single correct explanation of any phenomena or a single definition of any concept (p. 156)." In responding to question 5, Carr et al. point to the need to let students know 'the rules of the game' for the development of ideas in science. Teachers should encourage students to recognise that whether or not a proposed explanation is better than others is related to the notions of elegance, parsimony, and greater connectedness as well as those of plausibility, intelligibility and fruitfulness.

In his discussion about the role of explanations in science, Horwood (1988) refers to the work of Roberts (1982, cited in Horwood, 1988)) who developed the concept of curriculum emphases in science which are defined as a set of coherent messages to the students about the nature of science contained implicitly within the curriculum. Three of the seven emphases refer to explanations, which he labelled "the 'correct' explanation", "the structure of science", and "the self as explainer" emphases. In brief, the duty of the teacher in the first emphasis is to explain things to the students using explanatory statements approved by the research community; in the second emphasis, the teacher explains things but the explanations are subject to scrutiny and are available for change; in the third emphasis, the teacher gives credence to the students' intellectual activity as explainers.

CONTENT FACTORS	TEACHER FACTORS	STUDENT FACTORS
• the nature of the content (material or process; specific or general) • importance of the concept within the course (examinable, central or peripheral) • micro/macro content levels • process/matter content attributes • is the explanation deductive, inductive or causative? • teleological and anthropomorphic explanations • is the information a law, a theory or hypothetical? • relational or instrumental knowledge • alternative conceptions (already present or could arise during teaching) • related experiences and problems • relevance to the topic in hand	• how the teacher understands knowledge (constructivist, positivist, objectivist) • teacher's subject matter expertise • teacher's pedagogical expertise • teacher's rational preferences • teacher's conception of "what is science?" • teacher's explanatory style (direct, comparative, Socratic) • teacher's aesthetic preferences • the education-control dilemma • teacher's philosophical position - technical, practical, emancipatory	• student age • student ability • student background knowledge in the subject • student knowledge in other areas • (potential source of analogies and metaphors) • student's conception of "what is science?" • available time and resources • group dynamics • motivational and interest factors • reason for choosing the subject • cultural influences • student language skills

Figure 2. Factors that may influence teachers' explanations.

What are Explanatory Frameworks?

Just as artists and craftsmen have particular styles, it is therefore likely that expert teachers use an artistic style or creative format within which they logically develop their explanations, arguments and questions. When crafting explanations, scientists, teachers and students are not free to use just any sort of explanation, acceptable explanations need to agree with the scientific consensus on the subject. Effective explanations also need to accommodate the content, teacher and student factors enumerated in Figure 2. Finally, an explanatory framework needs to agree holistically with science and experience and conform to the rules of explanation. These rules, or better, philosophical considerations, have been discussed for almost 50 years by science philosophers. Explanations can therefore consist of a variety of forms as shown in Figure 3:

Acceptable explanatory qualities	**Unacceptable explanatory qualities**
Precise	Intuitive
Complete or comprehensive	Vague or incomplete
Science theory-driven	Folk theory-driven
Empirical	Human action
Logico-deductive	Teleological
Inductive	Idiosyncratic

Types of scientific explanation

Deductive-nomological	Deductive statistical	Inductive statistical	
Holistic	Complete	Partial	
Theoretical	Relational	Empirical	Pragmatic

Figure 3. Types of explanations and applicable descriptors

Three of the most significant explanatory types are 1) deductive-nomological, 2) inductive-statistical, and 3) deductive statistical (Ruben, 1990). These terms can be explained thus:

Deductive-nomological. Explanation that uses deductive reasoning constrained by known general laws (e.g., Newton's Laws, inheritance laws, etc.). It is a rational, law driven, step-by-step generation of knowledge where the applicable scientific laws are preserved and obeyed. In such situations, laws are often more powerful than theories.

Inductive-statistical. This is *inductive* because the interpretation is the most consistent pattern or generalisation that can be derived from the empirical data. If the generalisation is found to be valid in every case (no exceptions) the relationship may become a law. It is called *statistical* because of the lack of a deductive cause-effect links between the relevant law(s) and the outcome; therefore, the interpretation is probably true in most case or most of the time (i.e., there is a high probability of the law holding but it is not certain).

Deductive-statistical. Deductive reasoning that is applied to probabilistic law driven situations. As in the previous case, the relevant laws do not hold incontrovertibly. It is the law(s) that are probabilistic. The interpretation is not induced from the data, rather the data is interpreted in a rational and logical step-by-step way to derive the best-fit knowledge.

Despite explanations being part of daily human interactions, effective explanations are constrained by numerous factors. These include content attributes, teacher and student characteristics and philosophical considerations. The purpose of this paper is not to confuse the issue but to sensitise teachers to the existence of a variety of influences that may compromise or if considered, enhance the quality of their classroom discourse.

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Comparative Study of TEE Chemistry Papers of China and Western Australia

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Abstract

The article examined the Tertiary Entrance Examination Chemistry Paper of Western Australia and China in 1995.

As a summative assessment, the TEE is an important standard for year-12 secondary students as well as for their schools. In Western Australia, all of the students in the State use the same TEE paper. Similarly, in China all of the students in the whole country use the same TEE paper.

Preparation of the TEE papers are both based on the syllabuses. They are similar in China and WA. So, to some extent, the TEE papers reflect the standards and levels of secondary chemistry education in both countries.

Comparing the TEE chemistry papers of China and WA, we can find that their structures are similar in many ways. Multiple choice, short answers and calculations are common components of them. However, their contents show somewhat different stress on basic theories of chemistry and properties of chemical substances: China emphasises the latter and WA lays stress on the former. Furthermore, China pays more attention to testing the ability of problem-solving and integrated understanding of students. WA pays more attention to a strong foundation of basic chemical theories and covers a wider range of knowledge.

Introduction

The Tertiary Entrance Examination is a big event both in China and Western Australia.

As a summative assessment, the TEE is an important standard for year-12 secondary students as well as for their schools. In Western Australia, all of the students in the State use the same TEE paper. Similarly, in China all of the students in the whole country use the same TEE paper. The numbers of students who take part in the TEE are about 4,000 and 600,000 each year in WA and China, respectively.

Preparation of the TEE papers are both based on the syllabuses. The are similar in WA and China. So, to some extent, the TEE paper reflects the standards and levels of secondary chemistry education in both countries. It is for this reason that I am interested in a comparative study of the TEE papers of WA and China.I would like to analysis the TEE papers in terms of their structure and content.

Comparative Structure of the TEE Papers

The structures of the TEE papers of China and WA are very similar. (See Table 1.) Multiple choice, short answers and calculations are the common components of them. In the TEE paper of WA there is an addition part - extended answers - that does not appear on the TEE paper of China.

Table 1.

Comparative structure of the TEE Papers

	part	Format	No. of Questions set	No. of Questions to be Attempted	Marks Allocated	
					%	absolute*
China		Multiple choice	30	All	56	84
WA	1	Multiple choice	26	All	30	60
China		Short answers	7	All	32.7	49
WA	2	Short answers	14	All	35	70
China		Calculations	2	All	11.3	17
WA	3	Calculations	5	All	25	50
China		-	-	-	-	-
WA	4	Extended answer	3	1	10	20

* Total score is 150 in China and 200 in WA

We all know that as a summative test carried out on such a large scale, the TEE has to be a fair, reasonable one. In other words, it must be objective, and have a high reliability and validity. It is for reasons of reliability that both countries select the multiple choice, the short answer, and the calculations as main types of question formats in the TEE paper. Those sorts of questions usually are referred to as objective test questions because they limit the choice of the person who marks them. In fact, in China as well as in WA the multiple choice questions are machine-scored. They both use a separate Multiple Choice Answer Sheet. The short answers and the calculations usually can be scored using a template that keeps the common standards for marking. In this way, the reliability of the TEE papers has possibly been achieved.

But everything has advantages and disadvantages: the objective questions are powerful to maintain fairness when scaling them; but it is hard for the multiple choice, the short answer, or the calculations to assess the students' ability of expression and coping with integrated subject matter. On the other hand, extended answers can achieve these goals, so there are 10% of all marks allocated to the extended answer in the TEE paper of WA. Unfortunately, there are not any of this type of question included in the TEE paper of China at present, even though some experts argue for using it. One reason might be that it is hard to mark because so many students take the TEE in China. In Jiangsu province alone, there are around 60,000 students who will sit in the TEE room every year. In WA there are about 4,000 students take part in the TEE Chemistry exam each year. Another reason might be that the dominant idea in secondary science education of China is still knowledge transmission. Students are expected to answer questions that have a certain answer instead of an open end. To answer an extended question is thought too difficult for year-12 students.

When we consider the marks allocated in the TEE papers, we will find they are very similar for the short answers in both countries. However, they are quite different for the multiple choice and the calculations. For the former, China vs. WA are 56% vs. 30%; for the latter, China vs. WA are 11.3% vs. 25%. If one takes account of the number of the TEE students in China and concerns about the convenience of machine-scoring, one would understand why such a high degree of marks is allocated to the multiple choice. The other rationalisation might be that WA TEE redistributes 10% marks from the multiple choice to the extended answer. By analysing the questions in the multiple choice one can find that there is nearly no calculation in the WA's TEE. On the contrary, many calculations are involved in the multiple choice section of the Chinese TEE. Roughly speaking, nearly the same percentage of marks is located in the calculations in both TEE papers.

Comparative Content of the TEE Papers

To compare the contents of the TEE papers of China and WA, the contents have been divided into three categories: the language of chemistry, the basic theories of chemistry, and the properties of chemical substances. The language of chemistry involves names, formulae, electron dot diagrams, structural formulae of chemical substances, and equations for reactions, etc. The basic theories involve structure of atoms, chemical bonding, redox reactions, chemical equilibrium, electrochemistry and so on. The properties of chemical substances include physical and chemical properties of elements and compounds. Of course, there are some contents that do not fit any of the three categories. For example, the mole concept is treated as a tool of calculation rather than as theoretical knowledge. Calculating the marks allocated for each of the categories, the result is shown in the Table 2.

Table 2.

Comparative content of the TEE papers

	Language of chemistry marks allocated		Basic theories of chemistry marks allocated		Properties of chemical substances marks allocated	
China	28	18.7%	49	32.7%	38	25.3%
WA	38	19%	88	44%	20	10%

Table 2 shows that the language of chemistry carried almost the same percentage of marks in both the TEE papers. However, the marks allocated to basic theories in the Chinese TEE paper are obviously lower than in the WA by about 11 per cent. Oppositely, the marks occupied by the properties of chemical substances in the Chinese TEE paper are higher than in the WA paper by about 15 per cent.

These results might tell us a number of things. Firstly, the language of chemistry is seen to be an important part of content in secondary chemical education in both countries. The language of chemistry is a tool for communication of chemists as well as between teachers and their students. The language of chemistry for learning chemistry is just like 1, 2, 3, is for learning singing. Secondary chemistry can be regarded as the first stage of chemistry. To be able to correctly apply the language of chemistry will give students a good starting point to learn more chemistry. In addition, it is a hard task for many students to represent chemical substances or chemical reactions in symbolic form or in jargon rather than in everyday language.

Secondly, China put more emphasisis on the students mastering the properties and reactions of chemical substances; the marks allocated China vs. WA are 25.3% vs. 10%. WA pays more attention to the students' grasp of basic theories of chemistry; the marks equal 32.7% and 44% for China and WA, respectively. Many conceptions demanded in the TEE of WA are not taught in Chinese secondary schools. Ionisation energy, electronegative of an element, equilibrium constant and standard electrode potential are the instances of these. On the other hand, the preparation and properties of nitrobenzene and the reaction between NH_3 and NO are only included in the Chinese TEE paper and syllabus.

Comparative Requirements of the TEE Papers

It seems true that the Chinese TEE paper requires higher problem-solving skills and integrated understanding of knowledge, but WA calls for a wider range of knowledge and applications. For example, to test the properties of ions, the following question is taken from the Chinese TEE:

> Each of the following examples is a set of four water-solutions. In which one of the sets could all four solutions be distinguished from one another by reactions between themselves only.
>
> A. hydrochloric acid, potassium hydroxide, potassium sulphate, potassium carbonate;
> B. sodium chloride, hydrochloric acid, ammonium chloride, potassium hydroxide
> C. barium chloride, calcium chloride, sodium sulphate, potassium nitrate
> D. potassium hydroxide, potassium carbonate, magnesium sulphate, potassium hydrogencarbonate

To answer this question, a student has to remember many facts including propositional knowledge (name of the compounds, solubility of the compounds) and procedural knowledge (designing a rational procedure). Similar questions in WA's 1995 TEE exam were Question 13 of Part 1, and Question 8 of Part 2. The demand in solving the WA questions are less than for the above question from the Chinese paper.

Below is a copy of question 13 Part 1 of WA' TEE:

> Each of the following examples is a set of three water-solutions. In which one of the sets could all three solutions be distinguished from one another by colour alone?
>
> (a) ammonium dichromate, diamminesilver(I) chloride $[Ag(NH_3)_2Cl]$, sodium bromide
> (b) calcium chloride, mercury(II) nitrate, potassium chromate
> (c) cobalt nitrate, cobalt sulphate, sodium carbonate
> (d) copper(II) sulphate, silver nitrate, zinc nitrate
> (e) nickel sulphate, potassium dichromate, zinc chloride

Some Chinese educators believe that asking students to solve a problem in a new situation that differ from the one students have been familiar with can test the quality of their understanding. They also believe that the more variables the student is able to cope with the richer knowledge the student possesses. So in the Chinese TEE students were asked to draw an electron dot diagram for CH_3^+ instead of H_2O or even NH_4^+, and to write a structural formula of an organic molecule which is a product of reaction between $(CH_3)_2CH^+$ and a solution of sodium hydroxide. However, this reaction does not occur in the syllabus or textbook.

Moreover, there were some questions harder than those described above, such as the following one.

> Two organic compounds A and B have different formulae. They all consist of carbon, oxygen and hydrogen or any two of them. No matter in any ratio that they are mixed, as long as the total number of moles of A plus B is fixed, burning them completely will consume a fixed amount of oxygen gas and produce a fixed amount of water. So the formulae of A and B might be__________________.

Indeed, some students can do those questions as a result of depth of understanding. But some are successful only because of over-hard training. This training makes them study in school from 6 am to 10 pm. Even though government and experts strongly oppose this practice, the effect of their protests is very limited. Too many year-12 students face too few universities. This is a big problem in China. The students are forced practice the problem-solving skills again and again and lose the opportunities to broaden their range of chemical knowledge. From this respect, China could learn from the system of chemical education in WA.

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Looking for Social Justice in School Science: Reconstructing School Science Stories

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Social Justice and Science Stories

A number of papers have been published recently that present rationales for the existence of many sciences rather than one unique science (Ogawa, 1995), of the need for multicultural perspectives in science (Stanley & Brickhouse, 1994) or the need for anti-racist science education (Dennick, 1992, Hodson, 1993). All these authors critique, to a greater or lesser degree, the type of science that continues to be portrayed in school science text books and which is often presented as 'the science' in science classrooms. Historically, the prevailing representation of science in school science tends to consist of a science that is conducted by white, middle class or wealthy, European males. Stanley and Brickhouse (1994) describe this as an implicit committment to a universalist notion of science. Such a notion protects science against incursions from multicultural perspectives because it consists of beliefs that support the existence of one true science. Universalist science is characterised by a number of fundamental beliefs. Firstly, that there is a direct correspondence between reality and our observations of that reality. This notion is called naive realism. Secondly, that there exist universal truths or scientific facts that can be uncovered by the application of one true scientific method. This notion provides a protective belt against the multicultural push for a relativistic view of science. Finally, that scientific knowledge is value free and that the beliefs and values of scientists, and of the culture to which they belong, have no influence on the type of research that is conducted or the knowledge that is produced.

I do not believe that this is an accurate portrayal of contemporary science but it tends to be the type of portrayal that informs the science that is presented in schools. If we wish to have a socially just form of science we need to acknowledge both the contribution of people from a broad range of backgrounds to the development of science and the dynamic interaction between science and culture. If we wish to develop science curricula with a social justice perspective we need to appreciate the social context in which scientific knowledge evolves.I argue that this is not a move to rampant relativism in science because appreciation of a variety of views does not automatically mean that anything goes with respect to recognising new knowledge. Some forms of knowledge are more valued than others. Conversely however, belief in relativism does not ensure that marginalised voices will then be heard in science. Instead, acceptance of multiple perspectives allows us to present a richer picture of science. As Helen Longino (1988) argues, "scientific knowledge - although not the product of some uniquely truth producing method - is nevertheless a specific form of knowledge" (p. 574). If this means that we can no longer posit a misleading and simplistic universal notion of science then we should instead present a richer, more interesting and more representative picture of science.

An examination of the following questions might sensitise us to the need for multiple perspectives if we are to develop a socially just science curriculum. What is valued in science, who values it, and where is it valued? These questions might be useful to consider when we examine the type of science represented in science text books and popular literature especially the type of science represented in the stories that they tell.

Stories in Science?

Some of you might wonder what sort of stories I am talking about. You might argue that science is mainly about facts not stories. You might say that it is facts and theories that are taught in school science, while stories are used purely as anecdotes by the teacher or the text to make science more interesting for students. You might further argue that stories are not an integral part of science because they are about fiction not facts. Some readers might think that they could possibly accept the importance of 'accounts' in school science because accounts are used to link facts together within a time frame. These accounts help us to explain concepts or processes to students but they are based on facts and, therefore, these accounts could never be described as stories. For example, 'the life cycle of a gnat' could constitute an account or a description because it combines all the facts about the life of a gnat into a temporal frame but it is not a story.

However, I wonder is it possible in our account to include all the facts about a gnat's life that are available to us at that time? If it is not, who decides which facts to include and which to leave out? What implications do the selection of facts have for the meaning that we impose on the account? I argue that once ideas are presented selectively in science no longer are we telling 'the facts'. We are instead telling a story. In the following sections of this paper, I examine some of the stories that have been presented either in texts or in popular literature and suggest how we could retell these stories from a more socially just perspective. As teachers and educators, we need to be aware of both the power of story and of the philosophical assumptions that underpin stories, particularly as these assumptions might be at odds with our emerging views on the constructed nature of scientific knowledge and of the contribution of marginalised groups to this construction.

Stories are used extensively in school science because students (ie., novices) are believed to lack knowledge about science (ie. 'situated' knowledge) so text books and teachers use stories to help students make sense of the grand narrative of science. Thus, stories are used to help students organise their knowledge into explanatory frameworks which serve them as interpretive 'lenses' from which to comprehend their experiences in science. Even stories about the natural world reveal the author's values and attitudes (Pagano, 1991). Stories and narratives are used in school science because they are believed to facilitate learning. Consequently, narrative structure in school science serves to assist in the construction and transmission of a particular notion of the culture of science. However, I hope that narrative can also assist to transform school science. Because science stories reveal implicitly something about the nature of science, they serve to legitimate particular philosophical frameworks in science which may not be consistent with contemporary developments in philosophy of science or educational practice. Do these stories help us to move towards social justice in school science?

According to Dennick (1992), multicultural science education provides a science curriculum which recognises the contribution to the development of science of other cultures apart from white, Western European cultures. He argues that a Eurocentric perspective in representations of science leads to a misrepresentation of the existence of scientific knowledge construction in countries like China, India and Egypt that historically was consistent with 'genuine science' practiced by Europeans. In other words, universal science tends to posit that only Western Europeans 'do' science. He argues further that the contribution of Islamic scholars to the development of science in Europe has been either ignored or misrepresented as merely translations of ancient Greek texts.

In recently published text books there has been a move to recognise the contribution to the development of science of women and people from other cultures, and to remove the gendered focus of textbooks. For example, a human biology text book commonly used in Western Australia evolved from being called *Man in perspective* (1979-1989) to *Human perspectives* (1990-1995).

This move comprises one section of an historical continuum. In the beginning, women and other marginalised groups were not the subjects of stories presented in science textbooks. Firstly, there emerged the "affirmative action" photographs (Brush, 1985) in which women scientists, in particular, could be observed but were not referred to in the text of the book. Then, in recently published textbooks, we find examples of what I have called *politically correct science stories*. I use the term 'politically correct' because, although I hope that these stories have emerged in texts as the result of a more enlightened appreciation for the role of marginalised groups in science, I wonder if their inclusion is a political rather than an ethical decision. Let me illustrate what I mean by examining the implications of two stories that demonstrate a move towards a more politically correct perspective in their tales of the development of vaccination. The first story in Figure 2 comes from *Biology for the Individual: War Against Disease* which was published in 1974.

> Look round your class - if you were all living in 1780, ten people in a class of thirty would be dead from smallpox by now.
>
> But at least everyone knew that you couldn't catch it twice. So parents sometimes gave mild attacks of smallpox to their children deliberately. Unfortunately, no-one knew for certain how to produce a 'mild' attack of smallpox. So many children died from being given 'mild' smallpox.
>
> Fortunately, a British doctor called Edward Jenner became interested in finding a way to prevent smallpox. He heard that girls who milked cows often caught a mild disease called cowpox. After they had caught cowpox, they never seemed to catch smallpox. So, in 1796, Jenner tried the experiment on the next page.
>
> (Reid & Booth, 1974, p. 29)

Figure 2. A 1974 story about vaccination

Contrast this story with one about the same topic published in 1994 and presented in Figure 3.

> The old Turkish women who ingrafted their families were in fact injecting some smallpox viruses into the blood. This stimulated the body to produce antibodies to combat the foreign particles and destroy them. These antibodies remained in the blood and protected the people against further attack by the smallpox virus.
>
> Some years after Lady Mary Wortley Montagu ingrafted her young daughter, Edward Jenner developed a safer, more effective way to protect people against smallpox. He once overheard a milkmaid say to another patient that she could never catch the disease because she had the cowpox. Jenner never forgot that remark and on the 14 May 1796 he vaccinated a small boy, James Phipps, from the cowpox pustule of a milkmaid, Sarah Nelms.
>
> (McAllister, 1994, p.239)

Figure 3. A 1994 story about vaccination.

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I note some developments towards a more socially just perspective in these two stories about vaccination that were published twenty years apart. Firstly, in the story by Reid and Booth (1974) only the males are identified while in the story from McAllister (1994) all major participants in the vaccination story, males and females are identified. Secondly, the more recent story acknowledges the contribution of a non-Western European group to the development of conceptions about vaccination. Finally, the contribution of Lady Mary Montagu to introducing ingrafting to English shores is noted in the more recent story. Perhaps these stories indicate a development towards recognising the contribution of women and other groups to the development of science and also a greater sensitivity towards recognising, where possible, the contribution of all people, not just the males, to a particular episode in science.

However, we can read a different version of this story in Margaret Alic's *Hypatia's Heritage*.

> Milkmaids had long known that exposure to cowpox provided immunity to smallpox and variolation [a type of immunisation against smallpox] had been practiced in China, India and the Middle East for centuries, but it took a brilliant and intrepid Englishwoman, Lady Mary Wortley Montagu (1698-1762), to introduce the practice to Britain and the rest of Western Europe. In 1717 Lady Mary travelled to Turkey with her husband, the British Ambassador at Constantinople. There she first witnessed variolation. . . .
>
> On her return to England, Lady Montagu had her daughter inoculated and she succeeded in interesting Caroline, Princess of Wales, in the procedure. Under Lady Mary's direction experiments were conducted, first on half a dozen condemned prisoners, and then on six orphans. The experiments were successful and the Princess had two of her daughters inoculated. The practice spread rapidly throughout the country despite vehement opposition from both the medical profession and the Church. In a rebuttal to these attacks, Lady Mary published anonymously her *Plain Account of the Inoculating of the Smallpox by a Turkish Merchant.* Since variolation did occasionally result in severe disease (fatal in perhaps 2-3 percent of cases, as compared with 20-30 percent with naturally contracted smallpox), the popularity of inoculation declined, but not before the practice had spread to continental Europe and North America.
>
> (Alic, 1986, pp. 89-90)

This story indicates that perhaps Lady Mary Montagu's pioneering work in this area of science deserves more recognition than it is given at present in text book science stories that examine the development of vaccination. Edward Jenner did not miraculously think of vaccination all by himself but his awareness of the complexities and difficulties of vaccination were aided by work from earlier scientists and from community practices. Alic's story implies that Lady Montagu was a greater devotee of scientific practices than was Edward Jenner. After all she conducted multiple tests!

Implications for Teaching Science

From a purely social justice perspective, we need more stories in school science which recognise the role of women and other marginalised groups. An examination of the history of the development of science presents evidence of situations where a woman's contribution has been ignored, subsumed or stolen. Consider, for example, Lady Mary Montagu and inoculation or ingrafting, Anne Conway and vitalism (Alic, 1986), Lise Meitner and nuclear fission (Brush, 1985; Rossiter, 1993), Inge Lehman and the existence of an inner and outer core in the Earth (Brush, 1980).

In science stories the contribution of non-Western science has also been ignored or subsumed. For example, Hurons living where Montreal is now situated, were able to show French explorer Jacques Cartier a cure for scurvy in 1535 but Scot James Lind is recognised as the discoverer of the cure for scurvy which he proposed two hundred years later (Priess, 1993). Ibn-al-Nafis contradicted Galen's claim that blood seeped through pores in the septum of the heart in 1242, however, the discovery of pulmonary blood circulation is normally attributed to Michael Servetus (1553) or Realdo Colombo (1559) (Kohn, 1989). According to Sardar (1980), Islamic science was characterised by an appreciation of the relationship between the subject being studied and the appropriate scientific method which lead to an emphasis on using an appropriate method from one of many scientific methods. They were not constrained by the need to apply 'THE scientific method'. Islamic science also emphasised the need to understand and not to dominate the material being studied.

Joseph Needham (1969) in *The grand titration* argues that Chinese scientific thought was based on acceptance of a prototypic wave theory rather than a particle theory of matter that dominated Western scientific thought from the 17th to the 19th century. In contrast to Western scientific thought, Chinese scientific thought was essentially algebraic rather than geometric and was dominated by an organicist world view (Pepper, 1970) in which the parts are integrated into a whole rather than a mechanistic and reductionist world view which dominated Western thought. He argues that such a perspective inclined Chinese thinking "a priori to field theories" rather than the notion of action and reaction. Thus although Chinese science might not have demonstrated the theoretical underpinnings of Western science, it was based on theoretical structures. Chinese scholars carried out scientific investigations based on careful examination, awareness of the use of controls in experimentation, accurate measurement, systematic observation and meticulous recording and communication (Dennick, 1992). According to Needham (1969), a lack of written material about the processes that scientific artisans conducted can be attributed to social factors in China which discouraged the publication of technical details.

Women are ignored in stories in other ways as well. According to Brush (1985), there is a tendency for some text book authors to neglect to identify the scientists involved in a particular momentous discovery as female, leading most readers of the text to infer that the discoverers were male. Stories continue to under-represent the involvement of people other than rich, white males in the history of scientific development.

Teachers need to be ever vigilant of the tendency of textbooks to construct science from a particular perspective. The story presented below illustrates this difficulty:

Daily Life of the Neanderthals

> The hunters probably formed bands of about a dozen, while the women gathered berries, roots, and other plant food. Women probably also had the job of preparing hides for clothes, although the men would have skinned the animal. . . . Tool making would have been carried out by the men in the group and may have been done at special sites where the stone was available. There is no direct evidence for this division of labour between men and women, but the study of present-day hunter-gatherer communities supports it.
>
> (Newton & Joyce, 1995, p.141)

One wonders on the need of this text book to speculate on the roles of women and men in Neanderthal society in this way and, if there was a need, then perhaps there is also value in considering other alternative descriptions of these roles. The presentation of these scenarios in text books gives them certitude that they do not deserve. As teachers we could encourage students to be critical of the interpretation supplied in this story and encourage them to be involved in reconstructing this story from a different perspective.

If, as teachers, we want our classrooms to be socially just then we need both to consider the implicit messages in knowledge construction of the type demonstrated in *Daily life of the Neanderthals* and to acknowledge the contributions of other cultures to the evolution of science in all its variety.

Conclusion

All the stories presented in this paper represent a particular reading of the narrative of science. In most cases these stories under represent the involvement of people who are not white, middle class and Western European in the construction of science. Although there have been attempts recently to ameliorate somewhat this oversight, these attempts still seem to be captivated by universalist notions of science. As a consequence, they continue to present a gendered view of science ignoring the dynamic and powerful interaction between science and society.

As teachers, we need to be mindful of the implicit messages that underpin these stories and all science stories. What sort of story about science do we want to present to our students? We need to be conscious of how we organise and interpret events in science and of the prominence that we give to particular science stories. What we tell and how we tell it is a revelation of what we believe about the nature of science. Perhaps if we wish to involve students more in thinking about the enterprise that we call "science" we would do well to tell stories that celebrate the involvement of all in the development of scientific knowledge, rather than being tokenistic about this involvement. If we want students to learn to be critical about the stories that are presented in school science and if we want our science curriculum to be a socially just one, we need to encourage them to generate alternative stories that utilise other perspectives. If we do not provide this opportunity to our students, we may remain locked into a confining myth about what constitutes science. Consequently, science will continue to be uninvolving and uninspiring for many of our students and we will continue to encourage a lack of reflection about the nature of science and acceptance of a universalist notion of science.

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Portfolio Assessment in Lower School Science

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Abstract

Craigie Senior High is trialing portfolio assessment with all year eight science classes. The following points are the expected positive outcomes from using portfolio assessments.

1. To capture and capitalise on the best each student has to offer.
2. To focus on what the student knows and can do.
3. To be ongoing part of the their science classes that the student can use as a reference and/or reflection of their endeavours.
4. To guide the teacher as to what is needed in the teaching.

Our focus has changed to reflect developmental learning and problem solving skills rather than just factual recall of scientific concepts. The assessment profile now includes a wider range of learning evidence. This has also introduced science staff to outcome based education and helped stimulate "best practice" in science education.

Introduction

What is a Portfolio?

To use this assessment tool in the classroom it is important that we define what a portfolio is, however views about portfolios and portfolio practices are diverse. From ACER (Australian Council for Education Research) it puts portfolios into the following categories;

1. Working portfolios

   A Working Portfolio is the equivalent of the artist's studio ; the sketches, the notes, the bits of stimulus, the half finished drafts and the completed works. The best of Working Portfolios become an interactive context for on going instruction and feedback: a central curriculum and formative tool.

2. Documentary portfolios

   Documentary Portfolios are collections of students work assembled specifically for assessment. They contain not only final products of student work, but also evidence of the processes that students use to develop those products.

3. Show portfolios

   Show portfolios are purposeful selection of a limited amount of material designed to reflect the best of student work. They are used for a number of educational purposes including selection, certification and classroom assessment.

At Craigie Senior High our science portfolio is a mixture of the documentary and show categories and some educators would argue that our year eight model is not a portfolio as we do tell the students what materials must go into the collection. Despite this criticism, I am a believer that we need to model what is expected in such a collection of work. Then give more freedom to the students as they encounter more science in years nine and ten. There is no one "portfolio", there are many portfolios for different educational contexts and purposes. I like using ACER's simple definition of a portfolio as; **" a collection of artefacts of students learning experiences assembled over time"**

Background

In 1995 I was selected to participate in an innovative professional development plan called the *Secondary Science Teacher - Leader Training Project* run by the Education Department of WA, Science Teachers Association of WA and Curtin University of Technology. The aim has been to establish state of the art practice in science education. The workshops have been conducted throughout 1995 and 1996 and set over an extended time frame for the participant to be reflective on the information gained. Some workshops included:

What is the nature of science and learning?.........Different views of science
How do people learn?....................................Constuctivist teaching
How to include everybody...........................Gender and race issues
How to connect teaching with learning.........Strategies in teaching
How to do research into your own teaching.......Action research
A portfolio approach to teaching................Developmental learning
What is outcome based education?......Using this approach to teaching
How to involve others..............................Role as a science teacher leader

This has increased my knowledge and awareness of the major changes and current focus in science education. For the last two years I have taken a leadership role for my school trialing the latest methodologies in science education; becoming familiar with up to date research findings; developing curriculum materials based on constructivism principles; and communicating findings and methodologies to other science staff. I have conducted action research in my classroom as a means of helping me to collaboratively examine my teaching. This has given me an insight on how my students see me as their teacher and what areas I can critically look at to improve the learning environment on classroom interactions. Also using the resources developed by Dr. Mark Hackling (Head of Science Education - Edith Cowan University) I have been collecting and reviewing examples of students work using *open ended investigations*. This has given me first hand experience with using outcome based assessment materials.

Sharing my experiences with the staff at Craigie Senior High School I have used the portfolio assessment as a way of getting other science teachers involved in improving science teaching and learning. With my guidance the science department has done a critical analysis of the year eight science curriculum in the context of "Best Practice" to move towards a more relevant and useful science program. Changes have also included introducing group projects and competitions to improve students skills in problem solving and to generate positive healthy collaboration in their learning to enhance the enjoyment of their studies. This has had some success as many students have enjoyed the activities however others have done very little. This is an area that the science staff consider important and with some modification, (mainly timing) competitions within the school will continue in 1997. Providing an opportunity for "fun" to be put into the science curriculum for every student is an essential ingredient to the program.

Year Eight Portfolio Outline for Craigie Science

To develop a more relevant curriculum, and exploring better teaching practice the shift in methodology has been facilitated by the small changes to the course. Portfolios are been used as part of their assessment for all year eight students so that all science teachers can critically assess their worth. It has been agreed that the portfolios are to be purposeful collections of students work selected to provide evidence of their progress towards developing good scientific method in their learning. The extra dimension to assessment and positive student involvement in producing portfolios will hopefully improve this fundamental concept in science education. Teachers have been encouraged to use teaching strategies that assist in enhancing problem solving skills and explore assessment tasks that provides evidence of developmental progress in learning. This has increase teacher interest with Outcomes Based Education and they have been asked to adopted the following principles for effective learning in Science;

1. Taking account of students' views.
2. Recognising that students construct their own understanding.
3. Provide a supportive learning environment.
4. Learning in practice.
5. Engaging in relevant and useful activities.
6. Using scientific learning appropriately.

To make use of the well developed resources in the school the science teachers have not changed the year eight units but restructured them. Assessment outlines have changed to include a component of showing developmental learning and problem solving skills rather than just a heavily weighted profile of factual recall of scientific concepts. The resources that are in the school (ie. tests, practical activities, worksheets etc.) are still used but their importance has changed so that teachers can experiment with a wider range of evidence of learning.

As such, the science staff are learning more about Outcome Based Education and clearly are shifting the focus of the assessment profile at Craigie Senior High School. This has generated enough enthusiasm for the staff to look at changing the structure of the year eight science program to a more "Thematic" approach science in 1997. Over time and more experimentation with O.B.E. it is envisaged that the experiences in the science classroom also complement learning in other curriculum areas. As teachers feel more confident with a "Thematic" approach to learning goals this is an area that needs to be developed by the whole school over the next few years.

Setting up and management of the Portfolio has been a minimal task. The portfolios are A4 display files which cost around $1.50 and were placed on the book list for year eight in 1996. The files are kept in the science classrooms and are not to be taken home. At different stages of the year students have taken the portfolio home for parent comment, but usually kept in particular areas within the classroom. During a lesson a student may access the file to finish off incomplete tasks or maintain a journal.

Portfolio Goals

The following points are the expected positive outcomes from using portfolio assessments in the science classroom.

1. To capture and capitalise on the best each student has to offer.
2. To focus on what the student knows and can do.
3. To be ongoing part of the their science classes that the student can use as a reference and/or reflection of their endeavours.
4. To guide the teacher as to what is needed in the teaching.

Assessment Profile

Apart from trying different strategies in the classroom the assessment profile of the year eight students was changed. In the past the assessment has been heavily weighted on tests in the profile (up to 80%). For this year the assessment profile for each unit does change but a general outline is:

1.	Tests	50% (never more that this)
2.	Assignments, reports etc	20%
3.	Skills tests	10%
4.	Portfolio	20%

The assessment of the portfolio is an area that needs to be developed but at this stage the use of it is seen as a three way information platform. Firstly by the student to reflect on their learning by the marks given and producing new individual goals for enhancing future work. Secondly to be used by teachers to look at the work produced by the students and then reflect on what types of experiences are needed to develop science learning. Also I see the role of assessing student outcomes through carefully produced work tasks placed in the portfolio as a future direction in its evolution. Thirdly for reporting to Parents, the portfolio does give an insight to how the student is progress in their studies. The displayed work can give excellent account of how the student is performing with hard evidence to show to the parent. This year at Parent information evenings the portfolios have been used very effectively to show student's achievements over an extended period of work. Comments by parents have been very positive as it has provided them with very good feedback. Parent involvement is being achieved by looking at the areas their child has weaknesses and/or strengths in their science learning. Discussions then lead to what strategies can be used for improvement and/or development.

Portfolio Contents

Within each science unit the students have to include the following in their portfolio:

1. Goal sheet.

   The students are give an outline of the unit of work that will be done over the term. Here the student looks at what the outcomes of the science unit are and appraises it with their own knowledge.

Students then produce their own goal sheet on what outcomes they need to develop over the unit of work. This worked well at the start of the year however in later topics due to specific science jargon it was found that students were just copying down all the outcomes without using it to guide new learning. For 1997 this will change to a series of general questions on the topic for which they can write down their understanding of the science in question before the start the unit. Other questions will guide them to add what they hope to gain from the learning encounter.

2. Assessment grid

The students are to fill in a grid of their marks of any assessments made over the unit. Here they are asked to reflect on the teachers assessment and consider if it is a good or bad mark, or why they think a particular mark was given. At this stage students have not been able to re-submit work however this is an area that the science staff will consider in future years.

3. Two practical write-ups.

The students are to place two of their experimental write ups in the portfolio which are marked as part of the portfolio. The practical report is chosen by the teacher in the units early in the year. This has been done to model what is expected in the display. In later units the students may pick their own two practical write-ups that they feel show their best work. Also as part of the Craigie S.H.S. Development Plan, the literacy component focus has been to monitor that "Students will be able to write in appropriate text forms for each subject area''. The Science department has been able to monitor this in year eight over an extended time frame assessing developmental learning from the display of experimental write ups in the portfolios.

4. Unit reflection sheet.

At the end of the unit the students are asked to fill in a reflection sheet on what they learnt from the unit and any experience they felt was important in their learning. This sheet is very structured for the first units, then less structure is used on the sheets later in the year. This again is modelling what is expected in this document. It is envisaged that students can develop their own way of reflecting on particular science learning experiences in years nine and ten. With the change to general questions on their goal sheet for next year it is hoped that this can be used to help students in producing the reflection sheet, adding in any new knowledge from the learning experiences.

5. Journal.

This is a exercise book that students keep in their portfolios and are asked at times to write down individual experiences about different science concepts and their perceptions on why things happen. This book is not assessed formally but is given a small weighting to the portfolio mark to make sure that it is included. Its major use for the students is to develop their literacy skills and can be used by the teacher to reflect on what types of learning are taking place in the classroom .

Concluding Comments: Future Directions

Evidence so far using Portfolio assessment has shown that it has given the students some "ownership" of the science classroom. Some students have included a major assignment or a poster in the portfolio that they wish to display as a part of their best work. Some students have also included title pages for different sections of work to enhance their exhibit. This has helped in fostering positive work habits in science and many students have been eager to complete or "update" work in their portfolio if they have some spare time during a class. For 1997 the science curriculum and the portfolio will be updated for next years intake, moving towards O.B.E. Present year eight students will continue their portfolio in 1997. After this year of mainly modelling the portfolio it is hoped that the students have more input into what goes into their portfolio for assessing in years nine and ten. For the teachers using it as an assessment tool it has produced teacher discussion about "Best Practice" in science teaching and this by itself has to be good for science learning at Craigie Senior High School.

Reference

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Managing Equipment in Primary Science: New Skills for Experienced Teachers

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I come to this study as a teacher of 12 years service in both primary and secondary education. In my role as science coordinator at my local primary school I facilitated teachers' trialing and implementation of a new curriculum program called *Primary Investigations* (Australian Academy of Science 1994). Working with experienced teachers it became clear that they held a set of beliefs and experiences about science teaching and learning. Experienced teachers have a wide range of pedagogical knowledge of teaching but the lack of content knowledge and pedagogical content knowledge in science inhibits their attempts to teach science. Many of these problems, including the lack of science content knowledge, have been well documented by Symington (1980), Yates & Goodrum (1990), DEET (1989) and Appleton (1991). Teaching is a complex process and teachers' change slowly, unwilling to let go of their established patterns of teaching. Calderhead (1988) found that teachers faced with change in their teaching practice feel discomfort if the change differs from their accustomed method of teaching. Wallace & Louden (1993) found teacher discomfort with change is a particular problem for primary teachers, experienced and expert in other fields, having to teach science. Teachers in primary schools are expected to be expert in several fields but how can one person be equally effective in all areas, especially in science, if they had only studied biology as students? In 1989 a Federal Government study (DEET 1989) established that science education in primary schools in a state of 'crisis'. Jeans & Farnsworth (1992) established that teachers, when asked to rank the importance of subjects they taught, gave science the highest score. While many teachers' acknowledge science is important Shulman (1986) found they were unsure about how to incorporate new science programs into existing frameworks of teaching practice.

Many studies have focused on beginning teachers but what about teachers in the field who find themselves working with new programs to upgrade their expertise in a teaching area? The purpose of this study is to examine how two experienced teachers, comfortable teaching in other subject areas, introduced a new program of elementary science into their teaching practice. An interpretative methodology, defined by Erickson (1986) as "the immediate and local meaning of actions, as defined from the actors' points of view" (p.119), incorporating a constructivist perspective was utilised in the study. The constructivist perspective is given by Guba & Lincoln (1989). The study was conducted in two primary classrooms, one year two the other year five, in the state of Western Australia. Data were collected over a ten month period. Each of the classes was observed each week and regular interviews conducted with the teachers and students. The data consisted of field notes and interview transcripts and were used to construct several narrative vignettes of science teaching featuring the teacher and students. The vignettes were also used as interview triggers to gain understanding of the way in which these teachers engaged with the new science curriculum. These analyses were also shared with each of the participants as member checks to improve the authenticity of the data.

Lynley, the year five teacher, feels it is the duty of teachers to make sure students have a deep understanding of all aspects of science and technology to help them cope with their changing world. Lynley remembered a museum trip with her father as influencing her view of the importance of science. Her formal learning was in biology but she had always shown an interest in the physical sciences. Wallace & Louden (1992) suggest the importance of teachers' biography shows that, "few teachers have a strong basis of science content knowledge or pedagogical content knowledge" (p.512). Lynley preferred to teach older students because they are independent and easier to communicate with about interesting topics. Lynley was aware that her science content knowledge was inadequate and welcomed the new program as a way of increasing her content knowledge.

Leslie, the year two teacher, is a focus teacher in *First Steps* language which is a whole language program developed by the Ministry or Education, Western Australia. Leslie regarded me as her personal mentor in the new program because I had previously taught year two science. She agreed to participate in the new science curriculum because she felt unhappy with the way science was taught in the existing curriculum. Leslie had not taught science during the last five years because the previous schools had provided a science specialist. Leslie believed science was important and that it provided students with meaningful activities associated with the themes she was covering in language. Leslie's formal learning in science was biology. She was comfortable teaching science at a grade two level because she was unsure of her content knowledge when teaching higher grades. Appleton (1992) found that primary teachers lack confidence in their roles as teachers of science.

The new program relies on the supply of equipment to provide hands-on experiences for small groups. Both teachers had different backgrounds and experiences of science lessons and each viewed collection of equipment differently. A major contributor to the lack of science lessons was the difficulty in obtaining and organising materials according to Jeans & Farnsworth (1992). Leslie, being a junior primary teacher, was familiar with the need to supply equipment in her lessons and the school allocated a teacher's aide to help with the vast array of equipment necessary. Science was not her preferred teaching area but she had agreed to the new program if the science coordinator supplied her equipment. Lynley has the responsibility of supplying her school with equipment for the program but this is familiar to her as she has previously coordinated kits of equipment for a district science program. Both teachers experienced difficulties with equipment for a variety of reasons. This study uses vignettes of lessons to document reasons why experienced teachers have difficulties with equipment.

Bottle Divers

Today's lesson was based on bottle divers, which elaborated the concept of systems and the skill of analysis of a system by helping to identify the interactions within that system. A bottle diver is constructed using an eyedropper suspended in water, in a sealed 2 litre Pep bottle. When the sides of the bottle are squeezed the eyedropper descends due to a change in pressure. After my arrival at school Lynley and I moved to the staffroom to make an operational bottle diver for demonstration purposes. On examining the eyedroppers in the school supply we realised many had perished rubber tops which were hard to remove. As the students may need to insert a piece of wire to the eyedropper to ensure it's descent during the experiment, this became a problem.

"I used an eyedropper from home last night and it didn't cross my mind that these would be perished," said Lynley. "It just shows you how little some of the equipment is used around here."

"How will the students manage if they need wire?" I asked.

"Well, I didn't have to put wire in mine last night," said Lynley, "so I'll tell them to try the system without the wire and if they find they need the wire they will have to come to me to remove the rubber. They are really old aren't they?"

Finding the best eyedropper Lynley showed me how, by squeezing the sides of the bottle, the eyedropper descended to the bottom of the bottle. No matter how hard the bottle was squeezed nothing happened. Lynley checked for air leaks around the lid and the water level to see if less water would help. Finally a piece of wire was added to the eyedropper as suggested in the teachers' resource book. After each alteration the diver still resisted the pressure on the side of the bottle. We watched the clock tick around to the lesson time and felt the panic rising.

"When I did this last night it worked the first time," she said. "I should have kept it for the demonstration."

"If it worked once it must work again." I replied. "Let's go through the steps in the book one at a time and check we have done everything properly."

We read the through the instructions yet again, checked our equipment, left out the piece of wire, changed the eyedropper, lowered the water level and got desperate. As we struggled to make sense of the bottlediver I turned to the last piece of information available to us. The diagrams! There had to be a clue to the system through the diagrams. Like a jig-saw puzzle we checked each picture and then I saw it.

"There it is!" I cried. "The water level shows the eyedropper sitting just under the water level, the black line, and not above it."

We squeezed the bottle to pop the eyedropper out the top, made a mess, filled the eyedropper with a little more water and made sure it was just below the water level. Yes! it worked perfectly and did no harm to my credibility as the science expert.

Lynley addressed the students seated on the floor at the front of the classroom. She discussed the systems they had been working referring to a discussion she had with Judy, a girl in the class.

"Judy says many things working together creates a system of movement or a system that works," said Lynley. "If one of those parts doesn't work what happens to the system?"

"It breaks down," added Judy.

"It breaks down, good girl," said Lynley. "All right, so again today were going to be looking at a system. A special system and were going to try and relate this system to things that we use in our world today. Technologically, other things have been based on the principle that we are working with today. So we are going to be looking at a system. We are just going to look at this..."

"The thing in the bottle!" sang out Len.

> "Good Len," Lynley acknowledge. "A very simple system. I want you to watch it carefully. What can you see in the system? What is involved in the system? What have I in my hand?"

The students describe the items used in the bottle diver. Satisfied that the students were aware of the parts of the system Lynley went on to demonstrate how it worked.

> "All right," said Lynley. "I want you to watch the eyedropper in the bottle, just watch it. (she squeezed the bottle and the class went, Oh!) All right...lets have another look."

The class was suitably impressed and focused on achieving the magical bottle diver. Lynley went through the team skills and roles and the need for the group to listen to the student reading the instructions. The groups moved to their desks to read through the activity and gather the materials. Once they had accomplished this Lynley again called them to attention to discuss the need for care when operating the eyedroppers.

> "Now some of these," she began. "Boys are you listening? Rodney you don't know if you need it yet dear." She went on, "Your eyedropper may not need a small nail but today you have a piece of wire, all right. To take the rubber off the glass stem it should come apart. Now if you have difficulty in taking the top off yours would you please give it to the speaker to bring to me so that I can help you. I don't want you to tear the rubber top if it can be avoided. Don't you try and do it Dennis, would you bring it to Mrs. Pearson or myself."
>
> "Can you take the top of the eyedropper off?" asked Dennis.
>
> "You may not need to yet," I replied. "Do you want to try it without taking it off first. Try it without, read your instructions. If you need to put the nail in, which you may not, come back and I will help you but it's pretty well stuck and I don't want to move it unless we absolutely have to."

Lynley knew that she had time to organise the material and having problems at the last minute did not help. Being an experienced teacher she was able to overcome these obstacles but this meant explaining the lack of good eyedroppers. The students became concerned about the need to use the wire (nail) because it had been mentioned and it was shown in the diagram in their student book. Not allowing students the opportunity to manipulate the materials to investigate the phenomena could be seen as the worst aspect of prescriptive curriculum. Once the students began their experiment they focused on achieving the end result shown by Lynley and needed constant prompting by Lynley and myself to focus on what was happening within the system.

The following story of a lesson using magnets, to classify objects according to a criteria, raises other issues about the use of materials. Leslie had been assured by the school of assistance in assembling science materials. Leslie had shown the teachers' aide the list of requirements given in the master list at the back of the teachers' resource book. The teachers' aide had finalised preparation of material for the lesson. The magnets available from school supply were bar magnets of dubious magnetic strengths. In the preparation section for the lesson the teacher is requested to use small round ceramic magnets to disguise the nature of the magnet. The magnet story illustrates what can happen when the collection of equipment is left to the last minute and how lack of content knowledge about magnetic properties hindered the initial learning of students. Both Jeans & Farnsworth (1992) and Wallace & Louden (1992) emphasise a lack of time for the preparation of equipment and also how teachers concede that equipment is a major constraint in teaching science.

Magic Sorters

The second lesson in science for the year two class asked the students to sort objects into two groups by selecting their own criteria. The teacher was to give the students a ceramic magnet, a small round magnet used for fridge magnets, so they could put the objects into groups according to whether they stuck or didn't stick to the magnet. While the children were at recess I watched Leslie sort through the material and noticed that the magnets were long bar magnets and some were very old.

> "The magnets look very old Leslie, I wonder if they still work?" I asked.
>
> "The science coordinator, gave them to me," Leslie replied. "I know she had trouble getting hold of them but I assumed she knew which ones to get."
>
> "If you check the teachers' resource book it asked for ceramic magnets." I replied. "This is so the children can't identify with the shape and properties of the magnet before they start sorting."
>
> Leslie reiterated her initial response, "This was all Jessica could find in the school." and added, "My Monday is very busy and I didn't get time to sort the material. Jessica agreed to help us out with the material otherwise I would find it too hard."

We tested the magnets and discovered some were indeed weak but there was no time or alternative sources within the school to change them. The rest of the materials were arranged in an icecream container including the badges for the roles the children had in the group work. The children returned after the siren and sat on the mat with expectant eager faces.

> "Thank you class," Leslie said. "Last week we worked in teams to make a fish. Mrs Wilde (teachers' aide) has put a copy in your books and made a display of them on our back wall."

Having made links with last week's work Leslie went on to explained to the children that instead of paper shapes they would sort out a set of different objects into different groups. For the next 5 minutes the teacher went over the rules for the groups and the team work and team jobs collect material and return it safely and speakers who seek help for the group.

> "Okay, this is what is going to happen." began Leslie. "a student from each group needs to collect an icecream container which has eight different items inside. I want you and your partner to decide one way of sorting those little bits and pieces. Share your ideas and come up with one way of sorting those objects in the icecream container. After you get a little bit of time to do that we are going to stop and share our ideas."

The children moved off and after an initial discussion about who would do what part they were able to sort the objects using a variety of criteria. The teacher called them back to the blue mat after a while and asked the students to share the reasons for the groups they made using their eight items.

> "Well," Crystal replied, "we sorted ours from the ones that we can recycle and ones that can't."
>
> "I thought that was a very interesting one." said Leslie. "I don't think I would have thought of that interesting one. Thank you Crystal."

The teacher congratulate the class on the different ways they'd sorted the material and went on to describe the next part of the lesson.

> "Wowee!" said Leslie, "We have got some really interesting ways haven't we. I'm going to come around to your groups now and I'm going to give you something, some very special little thing that your going to use to help you sort all those objects in maybe a different way."

Darcy had worked out that it was hard, Nancy said it was metal. I 'accidentally' dropped a paper clip onto the magnet which stuck and the children thought it might be a magnet.

> "Ah!" Darcy sang out.
>
> "Oh! what did I do?" I asked.
>
> "Its a magnet." replied Darcy incredulously.
>
> "Its a magnet because they just do this," said Nancy. "They don't pick it up and fall down again it just picks it up because magnets can pick things up, if it picks this one up. Oh! it can't pick this one up, but it's metal."
>
> "I'll make it," said Darcy. "I'll make it go in."
>
> "Now you have done it," congratulated Nancy.

Obviously the magnet was not strong but Darcy was able to balance the paperclip well enough to get a result. The bell rang and the children were asked to stop and listen. The teacher gave them a sheet to help record the information by circling around the words, 'yes' or 'no', beneath the pictures of the items. During this recording activity a group of two boys had completed the sheet quickly but it transpired that only Mark had done the work. Andy had been busy sharpening his pencil. Mark had created his groups using a weak magnet and when Andy borrowed a stronger magnet it became clear that the groups organised by Mark were inaccurate. At my suggestion the boys worked through the activity again checking Marks answers.

> "It's different," Mark said. "I'll have to cross out that one."
>
> "Yes," I agreed. "Put a cross through it and then you might like to explain to your teacher that you had trouble with your magnet. What do you think then Andy?" I asked. "It works a lot better doesn't it?"

The majority of groups were able to arrive at the conclusion that some items would stick to the magnets and others would not.

Magic sorters, like the bottlediver story, relied on the supply of appropriate material. As was the case in both stories the supply of material was left to the science coordinator, a member of the teaching staff, with varying levels of expertise in this field. There was an assumption that the materials had been seen in the science stores and were therefore judged to be adequate. Leslie had only agreed to 'give it a go' if she had support in collection of materials. To make the task easier the teachers' resource book had a master list of materials needed for each lesson and Leslie gave this to the teachers aide to help in her preparation. The reliance on prescriptive curriculum enables teachers with limited expertise to conduct successful lessons. Shulman (1986) points out that teachers must not only understand answers to questions but they need a deeper understanding of the science concepts to pose subsequent questions to enrich the students' understanding. The gaps in content knowledge and pedagogical content knowledge are revealed by the underestimation of the importance of specific equipment which is essential and preferable to others.

A Conversation About the Stories

The stories were shared with the two teachers for reflection and comment about what they saw as the issued within the lesson. Both teachers commented on how the reading of the story made it all come back to them and both teachers acknowledged that the equipment had been a difficulty. When the reflections and commentaries where discussed with the teachers it became clear the issue of equipment acted as a lens through which the teachers understandings of content knowledge and pedagogical content knowledge of science was disclosed. The issue of explicit materials and teaching science places a reliance on cookbook experiments. This form of assistance for teachers revealed weaknesses in teachers limited content knowledge of science. Although seen to be essential in supporting the reluctant teacher the cookbook should be viewed as a tool in developing understanding of science concepts for the teacher as well as the students. These three major areas will be discussed in light of the data collected through the vignettes.

Content Knowledge and Management of Equipment

In Magic Sorters the lesson relied on the use of a ceramic magnet to enable the students to sort items into two groups. Leslie had limited experience teaching science but she'd been assured that the schools' science coordinator would supply all materials needed for each lesson. The science coordinator strengths lay in language and administration, not science. Leslie recalls her preparation for the lesson.

> "My first vivid memories were of the frenzied last minute search for the magnets, a vital piece of equipment for the lesson," Leslie recalled. "The magnets weren't in the place they were meant to be so I went on a wild goose chase around the school looking for them."

Leslie's lack of experience meant she had not appreciated the difficulties inherent in using poor magnets and how this would alter the students perceptions of their beliefs and abilities in science. The students initially grouped the items according to a criteria they chose, for example, round or not, blue or not etc. The lack of a functioning magnet meant, for many students, a lesson which created a sense of frustration and disappointment. Nancy knew what a magnet did but could not describe it well. When the magnet did not react as she knew it should it meant her original thoughts were not reinforced and her belief was shaken.

> "Oh! it can't pick this one up, but its metal," said Nancy.

Mark had worked hard to complete the activity without the help of Andy who had wandered off. He had to correct his work when Andy checked his original answers with a good magnet.

> "It's different," Mark said. "I'll have to cross out that one."

Leslie had not considered that for some students this was their first experience using a magnet and they would make judgements and discoveries about magnets based on faulty material. Yes, they would be able to sort the items but the experience with the magnets would promote alternative concepts because of this weakness. An activity that was designed to be a simple motivating look at sorting was frustrating and disappointing for some students in the class.

The bottle divers story shows that Lynley acknowledged the need to ensure that students have the appropriate equipment. Lynley had made a working model of the bottlediver the previous evening as she went over the lesson plan in the teachers' resource book. But she, like the students, had been able to reconstruct the model without fully understanding the principles of air pressures. Shulman (1986) investigated how teachers dealt with textbooks they found problematic due to a lack of content knowledge about the subject.

> "Two valuable aspects learned from the preparation and teaching of the "BottleDiver" lesson were," stated Lynley, "One, the importance of total preparation and two, to have complete awareness of the concept to be taught. Having successfully and easily trialing the bottlediver at home, was no presumption that this is what would happen at school. My 20 minutes at lunch time was not enough time with the school equipment."

We looked for clues in the steps set out for the experiment in the teachers' resource book. As a last resort we looked at the diagrams to see where the eyedropper should be. We both relied on the 'cookbook' strategies to overcome our lack of content knowledge about air pressure. Lynley realised she would have to look at ways of increasing her content knowledge of science. I was thankful to be able to solve the puzzle and have my content knowledge taken for granted. After the lesson I searched through the teachers resource book and found that it provided some additional information to assist my understanding.

> "When the bottle is squeezed the volume of the bottle decreases so more water is forced into the eye-dropper. As a result, the eye-dropper becomes heavier and sinks."

A note in italics, adjacent to the lesson steps, instructs teachers not to expect the students to be able to explain why the eye-dropper rises and falls but that it is enough for the students to view the bottle diver as a system.

Lynley felt frustrated with her attempts at teaching the students the real science of air-pressure but this had not been the intent of this particular lesson. It was enough that the students followed the steps to produce the bottle diver and recognised a system could be influenced when they interacted with it. Lynley's reflections on the overall lesson reveal how concerned she was about the need to have a good understanding of the concepts being taught in science lessons.

> "Teachers need to be aware of the students outcomes, the important steps of the lesson and inherent pitfalls." said Lynley. "They need to experience failure in the experiment themselves to understand the pitfalls, strengths and weakness that can occur in such a simple, straight-forward exercise. Understanding scientific principles is best learnt through trial and error."

Lynley and I had not understood the importance about the placement of the eyedropper under the water level with reference to air pressure acting on the level of water in the bottle and in the eyedropper.

Pedagogical Knowledge Transferred to Science Lessons

Pedagogical knowledge transfer can be identified in both vignettes. Calderhead (1988) and Shulman (1986) look at the interdependence of knowledge base and how teachers transfer pedagogical content knowledge from subject to subject to develop a generic pedagogical knowledge of teaching. Leslie was able to maintain the steps of the Magic Sorters lesson by adopting strategies she used in language lessons. These strategies included the grouping of students on a mat at her feet for whole class discussions which set the pattern of the beginning and end of the lessons. During the start of the lesson the students were given the main ideas of the lesson.

> "I want you and your partner to decide one way of sorting these eight objects. Share your ideas and come up with one way of sorting those objects in the icecream container. After you get a little bit of time to do that we are going to stop and share our ideas," she said.

Discipline management was transferred through the use of positive reinforcement of good behaviour when students were on the mat. There was also the ringing of a bell to call the students to attention ready for the next step in the lesson.

Lynley employed similar strategies. Although the students were older they too were sat at the front of the class for discussions and redirection. It was during this time that the roles and rules of group work were reinforced and special instructions about the use of equipment was delivered. Like Leslie, Lynley used positive reinforcement to discipline the students and she also used questioning of students to redirect their attention to the activity. Both teachers were able to compensate for their lack of content knowledge by transferring practised strategies for managing students from other subjects to the science setting.

Explicit Materials and Management of Equipment

In the study the teachers worked from a set of curriculum materials which explicitly laid out lesson sequences, structure, extensions, equipment and evaluation procedures. The explicitness of the experiments in the teachers' resource book was a valuable tool in the teachers' planning of the lessons and use of equipment. The teachers' resource book offered information about equipment, special preparation instructions and the quantities of materials required. Goodrum, Cousins & Kinnear (1992) found that although structures programs assisted teachers' understanding there were limits on the teachers' understanding of how students think. The teachers' resource book proved to be a benefit but also a limitation for both teachers because when good quality materials was not available the success of the lesson was jeopardised.

Typically, during science, Leslie read directly from the teachers' resource book during the lessons and carefully followed each step. This strategy was in contrast to her practice in other subjects where her programmes used ideas from numerous sources and had been modified over the years to suit her method of teaching. The teachers preparation notes, at the beginning of the lesson, defined the type of magnet. Leslie was unaware how important this information was to the collection of material and leaving this part of the lesson preparation to others resulted in inadequate materials on the day. Teachers in primary schools are under pressure to prepare for a curriculum full of subjects, teaching as many as six subjects a day according to Wallace & Louden (1992).

> "This was all Jessica could find in the school," she said. "My Monday is very busy and I didn't get time to sort the material. Jessica agreed to help us out with the material otherwise I would find it too hard."

Lynley memorised the lesson plan the night before and seldom referred to the teachers' resource book during the lesson. She was able to remember the sequence of the lesson and the questions needed to prompt the students thinking. When Lynley had to use wire instead of a nail some students focused on the need for wire because this had been emphasised in the instructions. Lynley and I spent much of our time

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encouraging the students to read their student book and follow the procedure and not just recreate the working model. Oral instructions is used in many subjects and the students were reluctant to refer to a student book for science instructions.

Although they had prepared for the lesson within the limitations of the time and available resources both teachers had experienced difficulty with materials. Leslie was unaware of the discrepancies between the list of materials in the master list and the refined list given in teachers preparation notes. Leslie had assumed the supply of materials seen in the science store room was adequate but this proved to be otherwise. The introduction of alternative materials caused the students confusion when they read their student book.

Conclusion

This paper examined several issues in relation to experienced primary teachers' use of equipment in teaching science. These issues included the connection between content knowledge and use of equipment, transfer of skills from other subjects and the benefits and limitations of explicit curriculum materials. These issues suggest several implication for the way in which teachers' knowledge is transferred from one subject to another and the way that knowledge develops in response to a new field of teaching.

Knowing why a piece of equipment is essential to the outcome of the lesson relies on teachers' understanding of the concepts. The year two teacher's perception of the lesson was centred on the students sorting items into two groups. The magic sorter was only there to give them another criterion for this sorting. When supplied with a set of magnets, with poor magnetic qualities, the significance of the inadequate magnets was not clear to her. The teacher was unable to appreciated the difficulties inherent in using poor magnets and how this would alter the student's scientific understandings. In the case of the year five teacher, she assumed that the material described in the teachers' resource book would be available at the school. She also assumed the equipment was a particular standard, with good quality eyedroppers and nails appropriate to the task. Having successfully trialed the bottle diver at home she was surprised when the demonstration bottle diver would not work. Neither of us understood that the system would only work if the eyedropper was submerged beneath the water level in the bottle. Thus, the teaching of science required a complex array of knowledge about the availability, suitability and quality of materials and the application of these materials to the pedagogical situation.

To a large extent the teachers were able to compensate for their lack of content knowledge by transferring pedagogical knowledge from other subjects to the science setting. The teachers were able to conduct successful lessons and complete all the steps suggested in the teachers' resource book. Their teaching experience helped them make decisions about alternative strategies and equipment when presented with inadequate equipment. The year two teacher chose to ignore the poor quality of the magnet and assumed that the students would be able to sort the groups somehow. The year five teacher substitute the wire for the nail and warned the students about not removing the rubber tops of the eyedroppers. Both teachers transferred discipline strategies from other teaching areas through the use of positive reinforcement of acceptable behaviour and whole class grouping for discussions and dissemination of instructions.

Explicit materials are a valuable tool for teachers with limited knowledge and confidence in a particular subject. Both teachers have limited experiences in learning and teaching science and consequently their content and pedagogical knowledge was underdeveloped. Explicit materials help to compensate for teachers' lack of science knowledge but student outcomes are not always assured. When the new program was introduced the teachers were offered the opportunity to peer tutor the lessons they would conduct with their students. The concepts at each year level would then be developed and understood, rather than being presented with a set of lessons. Both teachers' were unable to access this process and did not develop their understanding of the concepts. The year two teacher used the teachers' resource book as a constant reference by placing it on her lap during the science lesson. She was unaware of the need to check the material suggested in the master list with the preparation notes at the beginning of the lesson. The year five teacher memorised the sequence of the lessons without relying on the teachers' resource book during the lesson. When the material differed from that stated in the teachers' resource book and the student book, she had to spend valuable time explaining the lack of equipment to the students. This led to the students focusing on the equipment rather than creating a functioning bottle diver to demonstrate how a system works. Explicit materials need to be explained and refined to allow for the teachers perspectives which are created by their past experiences of learning and teaching in subject areas. Too often this is done at the expense of the students as the teacher tries to stay one step ahead.

Epilogue

When we were planning and writing this paper, we gave considerable thought to the 'voice' and whether it would be written in the first or third person. The vignettes and discussions are written in the first person throughout for the sake of authenticity but the paper was jointly planned and constructed by both authors contributing their ideas from their own perspectives.

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Polly the Pirate and Other Stories: Creating Contradictions in "Gender-Inclusive" Technology?

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The term "gender-inclusive" has become well known in Australian education over the last decade. In the preparation of the statements for the eight learning areas in Western Australia, an inclusive (including gender-inclusive) approach was mandated. Writers were required to make explicit in their document evidence that they had taken inclusivity on board. Thus, officially, Western Australian schools will be expected to provide a gender-inclusive education in science, mathematics and technology, as well as in all other learning areas.

If we are intending to promote "gender-inclusive" practice in science and technology education, we need to know what is meant by this term. We might define the term gender-inclusive to describe curricula and learning environments which

(i) incorporate, value and extend the prior experiences and learning; the current interests, needs and concerns; and the preferred learning and assessment styles of both females and males; and

(ii) challenge the dominant ways of thinking about science, mathematics technology and about the kinds of knowledge and behaviours that are valued and legitimated in those classrooms (Rennie & Parker, 1996).

A conceptual definition such as this requires some operationalisation to imagine what a gender-inclusive classroom will look like. Helpful descriptions for science can be found in Gianello (1988) and Hildebrand (1989), for example, and more generically in the *National Action Plan for the Education of Girls, 1993-1997* (Australian Education Council, 1993). As the first part of the above definition suggests, many of the strategies are not specific to science and can be applicable to other subject areas. The second part takes a more socially critical view of the curriculum and the way it is enacted in the classroom. In this paper, the definition is used to explore the extent to which the curriculum and learning environment in a Year 2/3 class is gender-inclusive.

Background to the Study

My collaboration with Jan, the teacher whose classroom is described in this paper, was part of a National Professional Development Project in Technology and Enterprise coordinated by the Mathematics and Science and Technology Education Centre at Edith Cowan University. Here, the focus is one small section of the Term 2 program in Technology and Enterprise in Jan's Year 2/3 classroom. Children were working on a technology task to design, make and appraise a model pirate ship in the context of a pirate theme developed by the class. It is not an easy class to teach; there are 31 children, including 12 with special needs.

The data on which this paper is based include field notes from several visits to the school and Jan's class, interviews with Jan, sometimes audiotaped and transcribed, informal conversations with some of the children, a videotape recording of one class, and inspection of children's work. To give a flavour of Jan's classroom and to place the discussion which follows in context, the following vignette has been constructed from field notes and the videotaped record of a Technology and Enterprise lesson in the third week of second term.

Description of the Lesson: Building Pirate Ships

> Despite the rain outside, it is warm and friendly in Jan's classroom. Models of pirate ships, in various stages of completion, occupy the centre part of the two clusters of desks. Some notes about magnets, a set of compass points, and some work on grids, using mathematics to create maps to find buried treasure, fill the chalkboard. Colourful paper fish suspend from the ceiling. In a corner, a table with beach sand, shells, flotsam and model pirate figures and boats is close to a display of pirate books. Nearby are two summary charts labelled "What We Think About Pirates" (among other things they are greedy, mean and spiteful) and "Facts about Pirates" (they attack other ships and have sword fights, for example). The back wall is decorated with a mural of pirates, drawn and coloured by the children, and including two female pirates. On the other side of the room, ample evidence of the children's active construction activities, as well as classroom equipment and useful gear overflow from a small storage area. Jan's loaded table is testament to the large amount of activity occurring in a busy classroom.
>
> The children hurry into the classroom after the lunch break, moving straight to their places to begin the afternoon's activities. Many put on pirate hats they have made on an earlier occasion and work with those on their heads. No one mentions the hats, they are just part of the atmosphere. Soon, and with no fuss, those children who want to paint their boats are at work with lots of poster paint and brushes on a group of desks protected by newspaper. On the other cluster of desks, two boys who have made splendid boats out of balsa word are painting with a turpentine-based paint. A mother of one of the boys hovers near, in case assistance is required, but she seems to be superfluous, so during the session she occasionally wanders around and is available to help other children.
>
> Every child is fully occupied during this session. Each has his or her own boat to work on. There is no angry or impatient word from anyone. When Jan stops the class for a word or two about using scissors safely, there quickly is silence, then children resume their work. Every now and then, children stop and look around. Sometimes they compare notes with another, offer advice, or explain their own plans. Some disappear for long periods, but they are working elsewhere, choosing fabric from a large selection housed in boxes in the passage to an open inside area, for example. Four or five children whose work is finished are playing with Lego materials, making figures for their boats and constructively passing the time. The classroom hums with activity; it doesn't seem noisy because there are no raised voices.
>
> Every one is cooperative, sharing, fetching, lending, holding things for each other. During the class, Jan remains seated at one of the desks, busy helping individual children with problems, but there is no long queue waiting for her, as for the most part, the children are very adept at helping themselves or getting help from their friends. The two Mums and a Dad in the class are also available to help. A lot of

cutting and measuring is going on, sometimes using trial and error, making adjustments until things fit. Then there is gluing and sticking, and comparing notes about adhesives to join things together.

I look carefully at the boats and talk to some children about their plans and designs. Many children designed their boat around boxes brought from home. Jan has a large supply of recycled and "junk" materials, so no child seems constrained by lack of resources. Most children amend their designs as they work to make use of materials they decided they like. It seems that girls are more likely to decorate their boats with bits and pieces of fabric, while the boys are more likely to paint theirs, but many girls are painting, too. Sasha is making a boat for lady pirates (she had drawn one of the lady pirates on the wall mural). She tells me it will have seats and a treasure chest with treasures and pictures of flowers on the wall. She has found some red lace material to help make her boat and is cutting it into shape. Kailie tiptoes past with her boat, holding her finger to her lips saying "SShhhh! My pirate's in bed!" Kailie explains to me the parts of her boat, which is dominated by a large bedroom in which her cardboard pirate, Polly, is in bed, covered with "blankets" which "she found in a cave". The other part of the boat has containers holding Polly's swords, and her rubies and treasure which she plundered after fights. The blue plastic circles (from bottle tops) attached to the outside of the boat, which I thought were portholes, represent the holes through which the cannons are fired, and Kailie has constructed a lever from a bent paper clip to fire them.

Michael's ship, made from balsa wood, is getting its hull painted black. The ship resembles a Spanish galleon, and his mother, who is one of the three classroom helpers today, confides to Jan that we, the visitors, probably won't believe that he made it himself. Michael tells me that his Dad helped tie on the sails, which are real canvas, with twine riggings. On the other side of this desk, Russell is carefully painting his balsa wood boat black and red, which he believes are the right colours for a pirate boat.

After a full hour, Jan calls the class to pack up. Tidying up is busy and active. The children know where to put things and they move fairly quickly, although some are reluctant to leave their work. It takes a good ten minutes, and Jan has to hurry along the stragglers to go to their next lesson. Finally, they are gone, the room is as tidy as it was before and the large amount of gear required has disappeared somewhere!

Development of the Pirate Theme

The pirate theme developed from work on the sea as part of social studies. Children showed an interest in ships, bringing models from home, and then pirates from Lego sets, and asked if they could make their own model pirate ships. The pirate theme continued for about two weeks and extended into every learning area. Early in the theme, children brainstormed what they knew about pirates, whether they were real or make-believe. Research using the available library books was used to help determine what was fact and what was fiction. The summary posters mentioned in the vignette were prepared and children wrote stories. Ben's story gives ideas which are typical of the children, while Prue's story is reminiscent of the grid work they did in maths related to treasure maps.

Pirates by Ben

> Pirates are mean and smelly and they kill people. They attack other ships and they fight with swords. They fire cannonballs at other ships and they find treasure. They have lots of jewels and money.

Pirates by Prue

> I know that pirates have to obey their orders. One spies at the top of the mast from the crow's nest. While the captain thinks "Where on the map is Mermaids Island?" He says "Pirate Scrubby, steer the ship west for ten minutes and then turn south. We should get to the island by dawn."

One child brought a newspaper cutting about pirates in Asia, and the children discussed pirate activities in Asian waters and the difference between today's pirates and those of long ago. Jan read them *Bad Pirate Pete* which led to a complex discussion of the moral issues about what pirates did and what they ought to do. The children decided that it was wrong for pirates to rob and keep their spoils. They considered it more acceptable if pirates robbed only the rich and gave to the poor, keeping only enough for their own needs. Children decided to write their own stories about Good Pirate Prue. At the instigation of the children, Jan took them all to see the movie *The Muppets' Treasure Island* after school one day, and they compared this story with the traditional story.

Assessment of the children's work was built into the normal class activities in an authentic way. Assessment in the technology task included both a written report of what children did and an oral presentation, during which they showed their model, told the class their plan, what they did, whether they succeeded and what they might do differently next time. Jan explains:

> We have to go back [to the actual models] and look at what were the things they were expected to be able to do. ... the design criteria they were given at the very beginning. ... I'll get them to evaluate each other. When I started to trial [peer assessment] last year, ... I couldn't believe it, how fair they were and how accurate. They usually use just a 0, 1 or 2, either they didn't meet it [the design criteria], they had a go and it was OK, or they met it really well. They're very, very fair with each other. And they actually evaluate their oral report as well.

Jan takes a child-centred, integrated approach to planning and implementing the curriculum in her class.

> I usually have something planned at the beginning of the year and then just see how the children's interests go from there. Whichever direction that takes, we work with that and then develop a whole integrated program from it.

She was a very experienced, confident teacher, and this approach worked well for her class. One theme slipped into another: A health lesson about the problems pirates had with preserving food, and the associated cooking session on "weevilly" biscuits, led to the next theme on insects and small invertebrates, which the children decided to call "creepy crawlies". Jan ensures that the appropriate skills and content in the various subject areas were covered some time during the term, and she often has the children help out with this planning. "I just have a checklist of all the things I have to do, and we negotiate. We say, look, this is the stuff we have to do, we've got this much time to get this done."

Are the Curriculum and the Learning Environment Gender-Inclusive?

Hildebrand (1989, p. 10) claims that "when the *goals and tasks, processes, timelines, products and assessment techniques* are negotiated and clarified at the beginning of a topic, students appear to feel more motivated and involved in their own learning" [italics in original]. Negotiation of the curriculum makes sure that children's prior experiences and understandings are built upon, their interests and concerns are valued and included, and their preferred learning and assessment styles are taken into account. In Jan's classroom, the effects of the negotiated curriculum were clearly evident to Jan.

> I can't believe what they're doing, they're surprising me every day. It's empowering them so much. As I've mentioned before, they're appraising me as well. If they think I'm not doing something that's the right shape or design, they'll let me know. And it's just such a totally different teaching style. They're like piranhas, they're just sort of draining me, they're just so motivated, and wanting to keep doing things.

The topic of pirates presents a challenge for a gender-inclusive approach, not only because pirates are stereotypically male, but because those pirates likely to be familiar to children are fictional characters belonging to a past, somewhat romanticised period. Captain Hook and the TV cartoon character Captain Pugwash are well-known examples, and each character had a look-alike drawn as part of the mural on the back wall. How can such a topic be relevant to children's current needs and life experiences? How can it build upon their prior knowledge, and how did the topic cater for preferred learning and assessment styles? Is the content of the curriculum challenged in a critical way? Or do pirates stay male and mean?

The most important consideration here is that the pirate topic is meaningful to the children because they thought of it themselves. It developed out of what they were doing in other subjects, and they negotiated the curriculum around their interests. In terms of the DMA task to build a pirate ship, children literally built on their prior knowledge and skills developed during previous construction work, but they pushed forward the boundaries of their skills as they learned new techniques. Encouraging children to bring their own designs to fruition, and using assessment techniques which compare children's outcomes against their own intentions, rather than some universal norm, caters for difference and diversity among the children.

In terms of the kinds of classrooms described as gender-inclusive, Jan's fits well. The physical environment is warm and supportive and children's work is displayed everywhere. Both boys and girls contributed to the "pirate table", which they set up themselves and they all seem comfortable in their classroom environment. Many authors suggest that in gender-inclusive classes boys and girls share equally in teacher interaction, asking and being asked questions, they work cooperatively and all are equally involved. In the lesson observed, all the children worked independently on their own model. Everyone was involved. There appeared to be no competition or envy over models of different quality. As the vignette shows, they were cooperating with each other. For example, one child was heard to tell another that masking tape would be better than glue for a particular task and went and got some.

Overall, the teaching, learning and assessment processes appear to be gender-inclusive. The content of the curriculum presents a more difficult challenge, one which it seems Jan has handled well. After drawing out children' initial ideas about pirates in a brainstorming session, Jan allowed them to extend and challenge their ideas through research and discussion. Past and present pirates were compared, their activities subjected to critique, leading to an idea of what a more socially acceptable pirate might be like – Good Pirate Prue. Despite the prevailing masculine and aggressive image of pirates (a browse through the library books on display in class confirms typical pirates to be male and mean), children refused to believe they were male only. Two girls, Sasha and Samantha, drew pictures of "lady pirates" (displayed in the wall mural) and several of the girls, including Kailie and Sasha, were making boats for lady pirates. Samantha's story makes it clear that she is happy for there to be female pirates (note the exchange between third and first person as she involves herself in the story).

Pirates by Samantha

> One day a pirate was sailing along and she heard a sound and it was a turtle having babies, so I helped it. Then I saw a big ship, it had male pirates in it. I feel scared. "Come on crew, we will fight!" Snip, snap, went the swords. "Now I've got you" said the girl pirate. Splash! "Yaha! We've got the treasure."

Contradictions?

Jan's class was busy, productive and self-motivated as children worked on their pirate ship models. The discussion suggests that the curriculum and the learning environment are approached in ways that might be described as gender-inclusive. However, the visible outcomes of the theme are not gender-free:

- Of nearly 30 pirate pictures on the wall, only two depict "lady pirates", both were drawn by girls.
- Only boys have used wood to make their pirate ship models.
- Only girls have extensive living quarters in their boat, and mainly girls use fabrics for decorating their model.
- Many (but not all) of the less-well-made boats are made by girls.
- The best-armed boats are made by boys (but Polly's boat had cannons and a mechanism for firing them).

Does it matter that the outcomes of this activity appear noticeably gendered? Do the differences in outcomes mean that the teaching and learning has not been gender-inclusive? Do the gender-stereotyped model boats create a problem for Jan or for the children? (or for you and me?) Is "pirates" an inherently gendered topic and hence one which should be avoided?

I want to answer no to all of these questions. My main reason for this is that I find it necessary to distinguish between the teaching-learning process and its outcomes. Allowing for differences and diversity in children's backgrounds, their needs and interests must allow for outcomes to be different as well. Negotiating tasks, making models according to their own designs and working in their own way, means that children's ideas are valued and incorporated into what happens in the classroom. Provided children have tried their best, the results of their efforts should be equally valued. It does not make sense to me to let children take control of their learning by valuing their input, but then to censure their chosen outcomes. The outcomes may be gendered if they are viewed as stereotypically representing children's interests, but there was no evidence that any boat was valued less by Jan (or even the other children) because of a lack of skill in making it. The construction skills of girls may initially be less practiced, but they, as well as the boys progressed well over the year.

The last question, that topics like pirates should be avoided, requires a more qualified answer. A topic which is inherently gendered provides teachers with opportunities to challenge the structure of gender in ways which enable children to begin to understand how males and females are positioned in the prevailing discourse and how some groups are privileged over others. The content of a topic like pirates is, of course, quite different to the gendered structure of the knowledge base of science or mathematics, but even in this Year 2/3 class, the teacher was able to help children to develop different views of who pirates are, what they might do, and what a more socially just pirate existence might be like. Opportunities to challenge the way we think about things, even pirates, are taken too infrequently in our science and technology classrooms.

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Primary Investigations: An Evaluation by Teacher Education Students

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Abstract

The paper gives an evaluation of the Primary Investigations curriculum project. The source of data for the evaluation was 125 teacher education students at Edith Cowan. All students had completed two course units of primary science education. In each unit the students used the Primary Investigations material in work with children. The students also had other opportunities to become familiar with the project. Data was obtained by using a 40 item questionnaire. The students could also make detailed written comment and participated in class discussions on the project.The paper provides comment on several dimensions of the Primary Investigations material.

This study was made because there is very little data available on student teacher reactions to the use with children of the new Primary Investigations curriculum project. Most evaluations of the project made to date, (Fetherston, 1995; Wallace and Louden, 1995; Happs and Coulstock, 1995) deal only with the reactions of in-service teachers. Another study made by the author (Rowe, 1996) and based on anecdotal data indicates that few Australian universities require their students to give significant attention to Primary Investigations. When it was noticed that students at Edith Cowan were making evalutive comments about Primary Investigations it seemed to be an appropriate move to attempt to quantify and record some of the available information.

All teacher education students at Edith Cowan have considerable opportunity to use and evaluate the Primary Investigations curriculum material. This study is limited to the Mount Lawley campus because the staff at Churchlands were much more closely associated with the development of the project. The students do two one semester courses of science education.

The first of these courses deals mainly with teaching strategies.The students apply these strategies in several lessons given to small groups of children brought onto the campus. In the past these lessons have been based mainly on topics selected from Western Australian Education Department materials (1980). In 1995 it was decided to use Primary Investigations as a source for lessons, because the project showed promise of widespread adoption, and because it provides considerable assistance for beginning teachers. Students used the material but, because formal studies of curriculum materials is not part of the first course, made no formal evaluative studies of it. Some introductory description of the material was included in lectures, but little comparative or evaluative comment was made.

In the second course in science education, taught in 1996, the students visited schools in order to teach a complete science topic to a larger group of children. For most students the topics were chosen from Primary Investigations. Students were instructed to prepare the first three lessons from the Primary Investigations material. In the second half of the topic students were encouraged to use ideas from other curriculum projects as well as Primary Investigations. In previous years the students would have done much descriptive and comparative work on a variety of well known science curriculum projects. In 1996 this work was replaced by a workshop on mechanisms for evaluating curriculum projects, and self directed study on student selected projects. Thus students received no formal evaluation of any science curriculum project directly from their lecturer.

Data Collection

After completing their science topic in the school, students were given a 40 item questionnaire requiring them to agree or disagree with statements made about Primary Investigations. The statements were mainly based on the informal comments about the project made by various students during the course. Space was provided for the subjects to describe the strengths and weaknesses of the project and to comment on other aspects of interest.The results of the questionnaire are shown in the Appendix. Of the 125 students who commenced the course some 111 completed the questionnaire.

Discussion of Results

Examination of the questionnaire results will show that in general terms the subjects showed a high level of satisfaction with Primary Investigations as an aid to presenting science topics to children. More specifically :-

1. General features of the project such as style, appearance, scope and sequence, and choice of topics were well accepted. (Questions 1-5)
2. The 5 E's was not favoured as as instructional model. This was problably because most students did not give it much attention with the absence of the normal inservice programme. (Questions 6-8)
3. The students were very satisfied with Primary Investigations as an aid to lesson planning and preparation. (Questions 9,11, 19-25, and 31-33)
4. A majority of students were satisfied with the quality and variety of activities presented in the progamme. A significant minority of students would have liked to see more choice and quality in the activities. (Questions 12-18)
5. The students were divided on the value of the assigned roles for group work. Again this was probably due to the lack of normal inservice. Some students were also concerned about the children's attitude and response to the lessons. It is suggested that they have inappropriate views about the role of curriculum materials on this issue and that they have insufficient awareness of the common difficulties of material centred lessons. (Questions 26-30)
6. The project was perceived to require supplementing in areas such as additional activities, integration with other subjects, and reference to other curriculum materials. (Questions 34-36,38)
7. Some features such as readings, black line masters, and illulstrations were very much appreciated. (Questions 37,39,40)

Anecdotal Comments

By far the most common reference was to the ease with which the Primary Investigations material could be prepared for presentation to children. Some 68 subjects were very positive about this. Perhaps this says something about the priorities of teacher education students. It also indicates that the project developers have been very successful in this area.

Other areas given much favourable comment were:-

The quality of the activities. (15 subjects)

The conservative equipment requirements. (11 subjects)

The interesting nature of the project material. (10)

Small numbers of subjects commented favourably on the illustrations, the background information, the assigned roles, the outcome statements, evaluation, the blackline masters, the levels of difficulty, and the student books.

Negative comments were made about the following:-

Lessons that are not interesting. (24 subjects)

The activities. (21 subjects)

The lack of references related to integration and other curriculum areas. (14 subjects)

The lack of choice for lessons and topics. (11 subjects)

Smaller numbers of subjects commented unfavourably on the assigned roles, equipment requirements, evaluation, outcomes, and background information.

These comments indicate that for many attributes of the project there is considerable disagreement .

Conclusions

The study indicates that Primary Investigations is generally found to be a valued and useful project by the majority of teacher education students at the Mount Lawley campus of Edith Cowan. A few aspects of the project are regarded negatively, and for some there is a division of opinion. Some of the major criticisms of the project relate to areas that the developers did not attempt to deal with.

Appendix

PRIMARY INVESTIGATIONS EVALUATION QUESTIONNAIRE

For each of the following statements about the Primary Investigations curriculum project decide whether you

Strongly Agree
Agree
Disagree
Strongly Disagree

Put a line through your choice. Feel free to comment further in the spaces provided at the end of the questionnaire.

1. The Teacher resource books are attractive and user friendly.

SA	A	D	SD
47	62		

2. The project has a good rationale. i.e. the basic approach is well justified.

SA	A	D	SD
22	79	3	

3. The project provides a good scope and sequence for primary science.

SA	A	D	SD
24	73	7	

4. The scope and sequence is hard to follow.

SA	A	D	SD
	7	80	16

5. There is a good choice of topics for each year.

SA	A	D	SD
13	61	2	

6. I used the 5 E s in planning my lessons.

SA	A	D	SD
	23	24	9

7. The 5 E s provide a good instructional model.

SA	A	D	SD
1	28	15	1

8. The instructional model was a useful aid to planning lessons.

SA	A	D	SD
9	50	17	1

9. The Primary Investigation outcomes helped me plan my lessons.

SA	A	D	SD
31	43	12	2

10. I could not see what concepts the outcome statements were directed at.

SA	A	D	SD
	18	67	8

11. The outcome statements provided for a good blend of process and conceptual objectives.

SA	A	D	SD
8	75	8	

12. There were insufficient process oriented activities.

SA	A	D	SD
3	25	59	

13. The project has plenty of activities.

SA	A	D	SD
13	54	21	1

14. I liked the activities I used.

SA	A	D	SD
23	63	15	1

15. The children liked the activities I used.

SA	A	D	SD
20	67	9	2

16. There were insufficient good material centred activities.

SA	A	D	SD
6	29	63	9

17. Most of the activities provided an opportunity for sustained work with three dimensional materials.

SA	A	D	SD
11	71	17	

18. Too many of the activities were mainly paper and pencil exercises.

SA	A	D	SD
2	10	77	9

19. The project gave plenty of information on how to present the lessons.

SA	A	D	SD
32	64	9	

20. It was easy to meet the equipment and material requirements of the lessons.

SA	A	D	SD
24	77	4	

21. I found the background information interesting.

SA	A	D	SD
22	67	11	2

22. The background information met my needs.

SA	A	D	SD
17	66	18	

23. The lessons were easy to implement.

SA	A	D	SD
21	81	2	

24. The children found the lessons interesting.

SA	A	D	SD
19	78	12	

25. The work was intellectually challenging for the children.

SA	A	D	SD
7	59	31	2

26. It was easy to keep the children on task.

SA	A	D	SD
8	53	31	6

27. The programme did not give adequate attention to the development of children's attitudes.

SA	A	D	SD
7	43	40	

28. I used the assigned roles.

SA	A	D	SD
3	40	35	

29. The assigned roles were too much bother.

SA	A	D	SD
11	40	36	7

30. The use of assigned roles for the children made teaching the lessons easier.

SA	A	D	SD
5	32	44	

31. The programme provided sufficient information on strategies for the lessons.

SA	A	D	SD
8	68	11	5

32. The strategies described were too complex and detailed to follow.

SA	A	D	SD
	5	81	12

33. The suggestions for recording and evaluating children's work were adequate.

SA	A	D	SD
3	76	17	2

34. I did not find the extension activities sufficiently challenging.

SA	A	D	SD
10	30	48	4

35. The Teacher resource book did not give adequate reference to a variety of other curriculum resources.

SA	A	D	SD
10	49	25	2

36. I found it necessary to use other curriculum materials for some lessons.

SA	A	D	SD
26	55	23	

37. I found some of the readings to be valuable parts of my lessons.

SA	A	D	SD
7	59	19	3

38. The programme gave adequate attention to the integration of science with other subjects.

SA	A	D	SD
2	43	50	2

39. The blackline masters were very useful.

SA	A	D	SD
12	60	14	7

40. The illustrations in the text helped me to understand what the lessons were about.

SA	A	D	SD
25	73	8	2

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'I do feel a little more confident': An Initiative in Primary Science Content

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Abstract

This paper reports an initiative funded by the Education Department to support primary school teachers to become more confident and effective in teaching science content. This initiative raises important issues related to (a) professional development (PD) of teachers and to (b) research in adult science learning. In relation to professional development, what are we asking of primary teachers when they teach science? Traditionally, science educators have focussed, in a variety of PD settings, on how content can be made 'teachable'. However, we also need to ask how can we develop primary teachers' pedagogical content knowledge if their content knowledge is limited? How can we expect primary teachers to make valid judgements about student learning in the conceptual strands of the Student Outcome Statements if these same teachers have limited understanding of related content? In relation to research, this initiative has raised an awareness of under-researched questions, including: What motivates adults to learn science concepts? What are major obstacles to their learning of science concepts?

The Role of Science Content Knowledge

A five day course was designed to provide a firmer basis for teachers in key areas of science knowledge, to increase their skills in translation of this into pedagogical content knowledge, and to develop skills in working with others as a presenter in science education. Support for this type of course can be found in many studies that define what teachers know and don't know about science, what forms of courses can have a successful impact, and they generally agree on the need for better levels of understanding on the part of teachers.

Smith and Neale (1989) investigated the subject matter knowledge and beliefs of ten primary teachers through interviews and videotapes of their teaching. They began their report in this way:

> Science teaching in the primary grades has been a persistent problem ... Teachers in those grades are under pressure to focus on reading and mathematics ...; in addition they feel untrained and uncomfortable with science ... Science is not allocated much time in the school day ..., and when taught is usually in a recitation format that relies mainly on a textbook (p. 1).

There has been a shift in emphasis from *process skills* to *content* in primary science (Kruger and Summers, 1989). They reported a study of the views of nineteen primary teachers about changes in materials: changes in a burning candle, a boiling kettle and other everyday phenomena. They note that primary teachers will not be required to teach about such changes in molecular terms. Nevertheless, an understanding of such changes may be necessary, because they believe that:

> it is difficult to see how children can be correctly led along an experiential path leading to understanding of changes in materials and the associated role of energy unless the teacher guiding them has some deeper understanding of the processes involved (p. 26).

The mismatch' between primary teachers' understanding of science concepts and the demands of the U. K. curriculum has prompted large scale programs in the UK (the Oxford University *Primary School*

Teachers and Science Project (PSTS) to address this problem (Kruger, Palacio and Summers, 1992). The Open University has produced a complete teacher' s professional development package in conjunction with the BBC, as a set of 6 workbooks with video support (see Tresman and Hodgkinson, 1993, and, Tresman and Fox, 1994). This was done in response to the National Curriculum and the evidence that teachers did not have sufficient science background to teach the key stages effectively. On this point, Summers and Kruger (1994) note that:

> ... in the past the science curriculum at the primary level has not taken account of the extent to which the teachers have knowledge and understanding of the concepts specified, or the ease with which these concepts can be acquired (p. 517).

Pedagogical Content Knowledge

The focus on pedagogical content knowledge has been stimulated by the proposition that unless teachers have the scientific models to contrast with student models, they are not likely to be able to foster their students' conceptual change. To be an effective science teacher, you cannot just be one step ahead of your students. It would be like teaching year 5 maths if you only have a 'personal best' of Year 6 maths.

In the course, participants examined the potential for lack of knowledge to be a dangerous and potentially misleading barrier to supporting student learning. They also discussed issues such as: is the time to learn the content with the students, or before them?; do the advantages of co-learning outweigh the potential for mutual misleading and non-learning?; and if you don't know why things float, will you be left with the option of sharing intuitive rules such as 'light things float'?

The need for better levels of understanding on the part of teachers, in order to improve students learning in science is described by Geddis (1993) as beginning teachers' simplistic views of teaching and learning, particularly the transmission view: 'teaching is telling and learning is remembering' (p 674). He then introduces 'the intellectual heart of the teaching enterprise': transforming the beginning teachers' content knowledge into pedagogical content knowledge. This is a process of transforming subject matter knowledge into a form which makes it teachable to a particular group of children. There are a number of aspects of pedagogical content knowledge: knowledge of students' concepts, strategies for teaching content, and shaping and elaborating the content. Smith and Neale (1989) concluded from their investigation that "staff development programs that focus on content-free skills and strategies, or even on particular curriculum packages [are] especially beneficial for teachers to focus on a particular content and the ways in which that content is translated in teaching." (p. 17).

These studies provided a strong basis for this course for primary school teachers and science leaders to 'upgrade' their science knowledge in response to the increasing importance of science lessons in the school curriculum. These courses cannot be just short term, as extending learning in many aspects of science as covered in primary science, requires long term commitment.

Effective Levels Of Science Knowledge

The majority of science educators agree on the need for more science content knowledge; however, the extent and depth of adequate levels of teachers science knowledge is under debate.

Symington and Mackay (1991) followed up the 1989 *Discipline Review of Teacher Education in Mathematics and Science* (Speedy et al., 1989) by surveying a sample of early childhood and primary teacher educators (19 in Victoria). The Report had recommended 'the equivalent of one unit of science discipline knowledge (including physical science) which is explicit and assessed'. The teacher educators who took part in the survey disagreed on this recommendation. Another study reports a study of 139 pre-science students' views about science teaching (Appleton, 1992). Several students 'felt a small amount of knowledge was sufficient for the teachers, provided they (approached) the teaching of it as co-learners with the children' (p. 17). For some courses, little change was evident: Gustafson and Rowell (1995) investigated the views of 27 primary teachers in a science education unit and reported few changes over 13 weeks of the views of learning, teaching and the nature of science.

Our experience with this course supports the view that extensive exposure of teachers to science content must be done in a way that links content to pedagogy, so the relevance and practical use of the content is paramount, in order to develop a positive view of participants to the material; and that such changes cannot be achieved in the short term, but require intensive and continuing education and support. The course described in this paper is a first attempt to meet these needs in pedagogical content, and to define effective levels of knowledge.

Course Outline

Participants met on three days, July 8, 9 and 10 in 1996. Fifteen of the eighteen teachers were also able to meet on days 4 and 5 of the course, on October 1 and 2. The five days of the professional development course to 'train the trainers' had as an important characteristic the emphasis on best practice in adult education. It involved an intensive introduction over three days. This was followed by a term's break, which provided a longer period of personal reflection and development with continuing contact with course presenters. The culmination phase, on Days 4 and 5, served to consolidate understandings and strengthen skills. This approach provided a model for trainers to use for their own courses.

The objectives of the course were to: 1. Increase participants' level of confidence in teaching science by increasing the level of participants' science understandings and skills; 2. Develop participants' skills as presenters of science content and in effective teaching by involving you in mini presentations; and 3. Through participants, to assist teachers in our schools to gain their own confidence in science content, and in turn, help their students to like science and to learn science effectively.

The course participants engaged in various activities to stimulate discussion of their existing concepts; evaluate their own, other participants and students' work in a cooperative mode; research aspects of their own interest; present mini sessions to other participants of how they would tutor concepts; refine their presentation skills, such as use of voice, eye contact, clarity, sequence, gestures and use of models. create models, develop analogies, draw diagrams and practice explanations; review effective questioning and response; interact with experts in the field eg Energy Research Institute, and experience environmental analysis work in a laboratory; develop an understanding of the links between *Primary Investigations*, the

Student Outcome Statements and their role in learning area statements and support documentation, and the developmental nature of science concepts and skills.

Materials were developed by the project leaders to support participants. The first three days of the course resulted in the production of a workbook of 66 pages, together with a set of 50 pages of supplementary readings. The second two days of the course resulted in the production of a workbook of 106 pages.

Course Evaluation: Phase I

At the end of the first three days participants were asked for feedback, to gauge the general strengths of the course format, to inform changes in format and design for the last two days, and to determine what content for the following two days was requested and should be included.

Responses indicated participants' awareness that one of the prime considerations of the course developers was to create an atmosphere where participants were free to recognise, confront and deal with their own misconceptions and level of knowledge. This characteristic of the group emphasis, the openness of the presentees to not being 'fonts of all knowledge' but being prepared to share their own science growth and the idea of science as a constant development of better and better theories, was mentioned as a key to the success of the course in days 1-3. Sample comments included:

- A great atmosphere - relaxed, informative and realistic.
- Ironically, perhaps it was my lack of understanding of such phenomenon as 'moon phases', 'the seasons' and 'floating and sinking' that proved to be most useful. Indeed there appeared to be very few who understood these concepts and this provided me with confidence to pursue an understanding of these concepts.
- In all the lessons I discovered that I know so little, so I enjoyed all of them. I still don't understand many of the concepts or even 'Why' but I do feel a little more confident in teaching these strands.

When asked about the relevance of sessions, and possible improvements, the majority of participants felt that all sessions were useful and relevant. Participants' comments supported that the period of five days was vital to allow participants to 'grow' into the mode of change, and to allow time for revisiting the concepts in different formats. This led to continuation of energy and chemistry strands in days 4 & 5, within realistic contexts such as water quality and weather patterns. The focus on presentation was given insufficient time in the first three days, but served to stimulate participants desire to learn more about it, which was given higher profile on days 4 and 5 with more extensive feedback and planning sessions. There is a clear need for a mechanism for trusted colleagues to give feedback to developing presenters - an impression supported by the final feedback when over half the participants indicated they would like to work with another course participate or a district science leader. Sample comments included:

- I felt all sessions were relevant - challenged old ideas and concepts.
- Initially I didn't want to hear any of the physics lessons as I didn't understand them, but they were presented in a simple format and paced at the right level so that I do feel a little better about them.

Requests for sessions focused on presentation skills, safety, links to local issues or habitats; the weather and the seasons; concepts of sound and forces; linking science concepts of chemistry and energy to our own bodies; and, understanding how these concepts are located in the Student Outcome Statements.

Course evaluation: Phase II

Reports from participants at the end of the five day course indicated that most moved from continuous models of matter and energy change, into molecular and atomic explanations for the first time. Reports indicated that for some, the course had helped them create more robust models of events, and promoted more skill in explanations and linking diverse concepts into complex events taught in primary school curriculum. Others reported that although they had met these ideas in high school, they were forgotten, and the course refreshed and consolidated their understanding. For some, it made the content of high schools classes understandable and relevant, with this content losing its mystique, for the first time.

For all participants, the course was very successful in stimulating a growth in science understandings; a desire to continue their own personal learning; an interest in working with others to share this new attitude and understandings. For example:

> Attending the course has in many ways undermined my confidence, which I have in sound measure in other areas of my work. However, I can now, on completion, see that this could become a strength to take on the challenge of re-education in this field and derive satisfaction and new confidence by doing so.

This five-day course contributed information on the desirable and achievable level of content knowledge for this type of intensive course. Feedback from participants indicated strongly that fewer days would not have supported such widespread change in thinking about the nature of science, personal conceptual change, and the growth of a positive attitude to personal change and construction of science knowledge. One participant noted:

> This course has renewed my interest in science and has helped me see it in a new light. It has brought home to me the fact that we can learn anything with enough time and clear enough explanation. The course has encouraged me to endeavour to find adequate explanations, examples and analogies to do justice both to science and the students. Emphasised again the responsibilities we have as teachers.

Participants were asked to assess how well they thought the overall aims of the course were achieved. The responses of the fifteen participants are summarised in the tables below. The number of participants choosing each category of response is shown in each table.

Q1 *To what extent has this course increased your level of confidence in teaching science by increasing the level of your science understandings and skills.*

Table 1

Level of Confidence

a little	1
to a reasonable extent	3
a lot	7
to a great extent	4

Over 80% of the participants indicated that there had been a substantial increase in their understanding of science content, to the extent that their level of confidence has been increased. Sample comments were:

- I want to read more physics and chemistry books because now I feel I can understand some/most of it.
- There was a large gap to fill at the start of the course from my background content knowledge, to what I'd need to bring about confidence in this area of teaching. At first, I viewed this as a negative, but now fell that I have a sense of direction to follow, and that confidence can be achieved, though in the longer term.
- The course has refreshed my memory - I have a science background which I haven't used for many years. I've taught science, but it hasn't been a priority in my program and I haven't taught it well. I think it's always been a "poor relation" to other subjects, but I have more confidence and inspiration now, to change this attitude.
- To explore some of the 'main' science concepts in a way that individuals could participate without feeling threatened or stupid.
- The 'scary' things like chemistry are not so scary - in fact when you do 'hands on' they're really quite simple.

Q 2To what extent has this course developed your skills as a presenter of science content?

This proved to be one of the key achievements of the course (see Table 2), and over half of those completing the five days saw the course as contributing in a significant way to their personal development as a presenter. The group varied from those who had never presented at all, to those with more extensive training or experience. The links between increased confidence in the content and presentation skills were made clear.

Table 2

Developed skills as a presenter

a little	2
to a reasonable extent	4
a lot	7
to a great extent	1

Sample individual comments included the following.

- By demonstration modelling and more indirectly though discussion throughout the course. I feel the course presenters and other participants offered valuable strategies and information, tried and true ideas for presentation of science content.
- A greater understanding of science content has enabled me to present with confidence.
- I do feel motivated to develop and improve my skills as a presenter, however I am sceptical about how to get an audience.
- I had already attended a 10 day train the trainer course which made me aware of the skills needed to present - only the content of the presentation varies.

Q 3. To what extent will this course through you, assist teachers in our schools to gain their own confidence in science content, and in turn, help their students to like and learn science.

Participants showed a more limited sense of success for this aim, perhaps due to an awareness of the limited extent of their control over factors in the broader school context. However, over a quarter felt that they saw the course as contributing a lot to this aim, as shown in Table 3:

Table 3

Assist others to gain confidence in science content

a little	2
to a reasonable extent	7
a lot	5
to a great extent	1

Sample individual comments included the following.

- Having been through the process of trying to "bridge the gap" in order to upgrade my science content knowledge, I now feel that I can relate that experience to the many teachers who remain apathetic to science teaching. Have genuine empathy as one who has so little science background, yet can see science as being important, yet fun. Definitely into demystifying science for those who feel it's beyond their scope.
- I've gone some way to making teachers in my school more aware of science content.
- I'm hoping my new found enthusiasm and knowledge of science content will assist teachers to develop their own levels of understanding of content.
- When teachers who know you see you presenting science in practical interesting ways - they tend to want to have a go and pass their new found knowledge on.

Rating Of Level Of Comfort

Participants were asked to rate topics they now feel more comfortable about helping others, using the three categories: Pretty confident (PC); OK with more research (OK); and Not confident (NC). The responses are summarised in Table 4. Participants indicated high levels of confidence for the two topics in *Working Scientifically* and *Energy & Change*, with increasing discomfort for the topics in *Life and Living* and *Earth and Beyond*. Both of these strands are traditionally seen as the province of primary science, so it is interesting that frequently taught concepts of plants, the moon and seasons are still proving conceptually challenging for the participants. This indicates the need to include these topics in future courses and to allow more time to come to terms with the concepts within these topics.

Table 4

Rating of comfort level

Strand	*Topic*	*PC*	*OK*	*NC*
Working scientifically	1. Fair testing	12	3	0
	2. Evolution of ideas	9	6	0
Energy & Change	3. Energy transfers	9	6	0
	4. Floating & sinking	6	9	0
Natural & Processed Mat.	5. Matter	7	7	1
	6. Water analysis	7	7	1
Earth & Beyond	7. The moon	3	9	3
	8. The seasons	1	11	3
Life & Living	9. Light & photosynthesis	4	11	3
	10. Inheritance & DNA	5	6	4

Participants were asked to indicate which topics they would prefer to tackle, and some were happy to work with a few topics they felt comfortable with, others felt able to tackle a much wider range. Others were more aware of the need to respond to the interests of the audience and choose to link to their needs.

Extent of Change Of Knowledge

Participants were asked to rate their change in knowledge from 0 (know or knew nothing) to 10 (know it all or knew it all), *before* the five day course and *after* the five day course. The average of participants' responses are given in Table 5. Results indicate a general improvement in all strands, with the highest average movement for water analysis, light and photosynthesis and fair testing. Individual movements were more varied, with little movement for topics of high familiarity (eg fair testing has been a focus of some individuals) and very dramatic movement for others (chemistry and matter topics). For many, apparently simple concepts were shown to be very complex to explain scientifically. In the words of one participant:

I was intrigued by the complexity and the number of science concepts involved in everyday occurrences. I was particularly intrigued with 'seasons' and 'phases of the moon'. The course greatly helped me to increase / fine tune my conceptual understanding, but more than this my approach to science, my perception of science and what science is about has been redefined.

Table 5

Mean self-rating of knowledge

Strand	*Topic*	*Before (0-10)*	*After (0-10)*
Working scientifically	1. Fair testing	4.5	7.6
	2. Evolution of ideas	3.7	6.7
Energy & Change	3. Energy transfers	3.1	6.2
	4. Floating & sinking	3.9	6.3
Natural & Processed Materials	5. Matter	6.6	7.3
	6. Water analysis	2.1	5.6
Earth & Beyond	7. The moon	3.8	6.1
	8. The seasons	3.9	5.8
Life & Living	9. Light & photosynthesis	3.8	7.0
	10. Inheritance & DNA	3.3	6.3

Discussion

This course provides strong support for an increased focus on the content involved in primary science in teachers' professional development. Significant change was observed and reported by participants, perhaps because of the high motivation levels of the individuals (they had to apply and be accepted) and the intensive but shared group focus of the activities (the five days allowed effective interpersonal relationships to develop of mutual trust and support), and the high value their participation was awarded by the course organisers and presenters (participants were seen as high achievers and very talented individuals). Increases in confidence levels, in a more positive attitude to continuing self education, and a desire to promote science content as a way of improving student learning were the three most powerful outcomes of this course.

The title of this paper supports our belief that changers in adults' long held views and concepts is a lengthy developmental process which brief 'one - off' PD sessions will not address.
Our experiences in working with this group of enthusiastic and dedicated professionals has raised important theoretical and practical issues relating to the identification of the most effective ways to develop primary teachers' content, and thus pedagogical knowledge in science, with the expectation it will assist them make valid judgements about the level of achievement of their students.

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Delivering an Inclusive Curriculum in Science: An Impossible Dream?

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Inclusive curriculum as it relates to science has been described in the literature as using a variety of teaching and learning strategies including collaborative learning, teacher-student interaction at a personal level, examining integrated concepts within a relevant context, providing equal opportunities for all students to handle equipment, delivering a negotiated content, and using goal-based assessment practices. The suggested strategies for inclusivity in science bear a strong resemblance to those advocated for early adolescent students in their middle years of schooling. There is, as yet, little research evidence to confirm that these practices do include more students in the science curriculum in our schools.

In this paper, links are drawn between the literature for inclusive curriculum and for middle schooling, then data from case studies of lower secondary students in Western Australia are examined to determine whether the suggested features of the inclusive curriculum and middle schooling are used in their science classrooms. The students' own perceptions are presented to see whether they believe that the proposed strategies do or would contribute to more positive attitudes to science. In particular, some girls' experiences are described in order to illustrate the effect they had on their perceptions about science.

What is an Inclusive Curriculum?

The term inclusive curriculum in science education has been defined as one which incorporates and values the prior experiences and strengths of all students, and allows them to participate in the curriculum by using a variety of learning styles and assessment techniques in a supportive and relevant context (Hildebrand, 1989). In discussing a gender-inclusive science education, Hildebrand (1989) argues that it would be beneficial for all students. The problem, in her view, is not with the students (that is, the girls), but with the teaching of science. It should involve much more active learning by the students with activities, such as drama and creative writing, which stretch across the curriculum. Reiss (1993) agrees that "what is good science education for one particular segment of the school population is good science education for all" (p. 41). He recommends practical work involving open-ended investigations, problem-solving, attractive laboratories, and role play of personal, social and political issues.

While there appears general agreement as to the desired strategies to be employed, there is little research evidence to support those assertions. Hildebrand (1989) admits that the strategies which she suggests 'may not all be necessary, although specifically which ones are sufficient is as yet unknown' (p. 8). There are, however, many similarities between the recommended strategies for an inclusive curriculum, and the desirable educational practices which are advocated for young adolescents.

Middle Schooling

The educational needs of young adolescent students have been addressed in a large body of literature from the US, UK, Canada and Australia, and contains much common ground. Students in lower secondary school are undergoing great social, physical and intellectual changes in their lives. It is generally agreed that, to cater for their growth, schools need to become more responsive to the students' needs (Anderman & Maehr, 1994; National Board of Employment, Education and Training [NBEET], 1992; NBEET, 1993). Hargreaves and Earl (1994) suggest that early adolescents have certain "rights of passage" which include

> rights to a rounded education, rights to learning that is relevant, imaginative and challenging, rights to wider opportunities for achievement and success, rights to routine review of their progress with someone who knows them well and rights to feel welcome and cared for in their school environment (p. 3).

Emphasising the capacity to think critically, to transfer knowledge and skills to other situations, and to take more responsibility for their own learning are vital in the middle years of schooling. These skills should be acquired in an environment which builds and maintains students' self-confidence and self-esteem (NBEET, 1993). Strategies which have been suggested to achieve these aims include authentic student participation (as opposed to token involvement) in planning their own learning; interdisciplinary approaches to make the curriculum more relevant; smaller learning communities to enable closer student/teacher and peer relationships; and flexible teaching, learning and assessment strategies to meet the needs of individual students (Cumming, 1994; Eyers, 1992). There are strong links between inclusive strategies and those promoted for young adolescents.

Science in Secondary Schools

Practices in science teaching in lower secondary schools and their effectiveness in meeting the needs of students are beginning to come under more scrutiny, especially in Australia. The Australian Academy of Science is currently initiating research to examine and improve teaching strategies and student learning at the lower secondary level ("Study of Lower Secondary Science", 1996). Some previous research examined the differences in attitude of students as they moved from primary to high school. In Victoria, Baird and Penna (1992) found that an overwhelming majority (93%) of students enjoyed science in primary school, but that they were disillusioned with science soon after beginning secondary school. They felt as if they just copied notes or watched demonstrations, and were not given any "real work". The students expressed their disappointment at the lack of activities, the amount of notetaking, listening to lectures, and the irrelevant topics (Baird, 1994; Baird et al., 1990). Similar findings are reported by the Department of Employment, Education and Training (DEET, 1992) and the Department of Industry, Science and Technology (DIST, 1995). It is important to note that nearly all of the students felt that science *could* be more relevant and fun if more practical activities were included.

In South Australia, Cormack (1995) used the concept of 'alienation' to investigate students' estrangement and lack of engagement during the middle years of schooling. The students' relationship with the teachers was the common theme which was linked to issues such as relevant curriculum, school structures and teaching strategies, and had an impact on students' engagement with school. Cumming (1994) encapsulated the issues which need to be addressed by teachers and schools in the "middle school":

> There is further evidence to suggest that for a significant number of adolescents the curriculum lacks relevance and cohesion; teaching practices are alienating or simply boring; and organisational structures and procedures are rigid and disempowering (p. 13).

Western Australian high school principals maintain that the tertiary selection requirements influence even the early years of secondary school, so that teaching "tends to be a headlong rush through the crowded curriculum with little time for higher order thinking skills" and "suffers from excessive content, bookishness, individualism, competitiveness, didacticism, force feeding, conformity and traditionalism" (Chadbourne, 1995, p. 4).

In the US, Baker and Leary (1995) interviewed girls who said that they disliked lectures and taking notes in science classes because they found such teaching strategies isolating. They preferred to interact with others, including the teacher, and made judgments about science based on their relational and affective needs. Baker (1995) found that girls had strong preferences for how science should be taught. They wanted problem-solving and hands-on activities, discussions, and more work to be done in small groups or with partners. "By eighth grade the teacher had assumed an important role in the science classroom. Attitudes toward science were often dependent on whether or not the teacher made the subject fun or boring. When science was perceived as boring or irrelevant the blame was often placed on the teacher" (Baker, 1995, p. 164).

Method

The case studies were compiled from data collected during a study in Western Australia which employed a longitudinal design and followed two groups of students from year 7, their final primary year, into secondary school. Data were collected at two levels: first, case studies of individual students using mainly qualitative data; and second, at a broader level, both qualitative and quantitative data were collected from the cohorts of the case study students. Semi-structured interviews were the main qualitative data source for the case study students. Field notes were taken during lesson observations, and were referred to in interviews with the students. The case study students were interviewed at the end of primary school, and during their first and second years of secondary school. In all, there were 16 case study students over the two stages of the study who were selected because of their enthusiasm for, and high achievement in, primary science. Four of these have been selected to illustrate the effect that inclusive strategies, or the lack of, had on the students' attitudes towards science.

Case Studies

Natalie

Natalie had been very keen on science for as long as she could remember. When she started attending the local government high school, Natalie did not show as much enthusiasm for science as she had expected. "It's just like a subject. I don't think of it as a good or a bad subject. It's just a subject that I have to do." Her teacher was friendly and conscientious, and most lessons involved an activity, but Natalie felt that her teacher did not "walk around and ask people questions and everything like that. He just stands out the front and does what he has to do". Later in the term, she considered that the special equipment and rooms for science were better than in primary school, but that the content and method of delivering it was not challenging for her. "I thought we'd be doing really interesting things, but we're not doing that interesting things, and it's not very different from primary school. ... I thought we'd be doing really interesting things like discovering new things, but we're not. ...I'd rather be given a question and asked to work it out for myself".

By the end of the first semester at the local government high school, Natalie ranked science as fourth on her list of favourite subjects, in the middle of the seven that she mentioned. She liked theatre best "because it's like really easy. ... [The teacher] is really nice. She's not like a teacher, more like a friend".

For Natalie, even though the class was often involved in practical activities in small groups, and the teacher was friendly, the science curriculum was boring, the tasks were not challenging, they allowed for no choice in methods, the result was already apparent, and the teacher did not relate to her personally. For these reasons, her attitude to science had become less positive.

Kym

For Kym, high school science was a great disappointment. She attended the local government school where her science teacher spent most of the lessons talking or writing notes on the board, and the class participated in very few practical activities. There was little to challenge her. "We haven't done anything really difficult where we've actually had to think much yet". By the end of the semester, the situation had not improved, with many students in the class complaining at the lack of activity work.

> Science is still not very good at the moment because it's terribly boring. All the other groups say they've been doing lots of experiments.... So we asked him if we could do an experiment, but he said that because of our topic we couldn't really do that. But then the subject that we did last term, transition [science], a lot of the other students did experiments and we didn't. We looked at the microscopes once, and we've watched a few videos, but that's basically because he had nothing else to do.

Science had become Kym's least favourite subject. Her marks had been good (27 out of 30 for the most recent test). Her favourite subject was "Probably English because I've got Mr C - he's a cool teacher". Kym's negative perception of science was mainly the result of the science teacher's style of presenting the curriculum which she found boring and unstimulating. Her science class had participated in very few practical activities, and the content of the lessons had not been challenging.

Rochelle

Rochelle was enthusiastic about all aspects of science in primary school, and always did well in tests. She attended a private girls' secondary school where science was not as activity-oriented as she would have liked. By the end of the first semester, although she had not given up hope, her enthusiasm was waning. Her science teacher was not as friendly and approachable as some others. She had achieved a B grade in first semester. Each topic was approached in the same manner, and the assessment was always a written test at the end. Rochelle's observations about the way science was presented illustrate her reasons for her reservations about her enjoyment.

> They can be a bit tedious if it's just going through work and doing assignments or just sheets. ...We've done a lot of topics, always following the same format. We always just go through the book, and we always have revision at the end, and I think we have a test after every so many. ...I think I might grow to enjoy different parts of it.

Rochelle felt that each science topic was presented in the same way, that is, by working through the book with a test at the end. This accounted for her decreasing enjoyment of science.

Elizabeth

Elizabeth was enthusiastic about primary school science, and wanted to be a nurse. After the first three weeks of high school, Elizabeth's opinion was that "It's good, but it's all work. You don't get any time to do any fun stuff". Her favourite subject was science because "I like doing the experiments, and the teacher's nice as well". She felt that her science teacher, Mr Giles, was more relaxed than some of her other teachers, and he was friendly to everyone in the class. She felt that secondary science was different from her expectations of it.

> I thought we would use much more of the book, but we haven't used the book so far, so ... and I thought there would be a lot more like taking notes and writing and stuff, but we only have to write up our experiment, and that's it.

Elizabeth's initial positive reaction to science at high school was based on her perceptions of the friendliness and relaxed attitude of her science teacher, and the hands-on approach he used to teach science. She was surprised but pleased that they had not used the book, as she preferred experimenting to reading.

At the end of term one, ten weeks into the school year, Elizabeth's feelings about science had not altered. She had received an 'A' for the term's work, and although the science "teacher tells us off sometimes because we've been talking too much", usually he was "really relaxed about it [teaching science]". Elizabeth was still impressed by the lack of text-book learning. "We do lots of experiments, and we take notes from that. Nearly every lesson we do some sort of activity." She liked science a lot more than in primary school because "The teacher's better. We do more of a range of stuff and we get to use more equipment. We didn't have any equipment at primary school." Science was still her favourite subject, along with Social Studies and Japanese, "because the teachers are nice and I just like the subjects."

Elizabeth continued to achieve well throughout semester one, and science remained her favourite subject. She felt that she was learning a lot of new and varied things, always through a practical approach. Her science teacher made her feel relaxed, and that was why she felt that she was learning well.

> We're always doing something different. We do the same topic, but we do different subheadings under that main topic, so I like doing that. We do quite a bit of experiments and practical work. ... He [the science teacher] is really nice, and he has a sense of humour. He keeps the class under control. And we were talking to him today, and we can say something to him, and he won't take that personally. Like if we say something to the other teachers, we just get busted. But he won't take it personally, and like we say stuff to him. We asked him how old he was, and he made a joke out of it.... there's no way that I would ask any of my other teachers how old they were!

So, for Elizabeth, her relationship with the teacher was a vital element in her enjoyment of a subject: "I have to like the work, but I also have to like the teacher to be able to enjoy the subject". Her determination to be a nurse had not diminished.

Lesson Observations

As the researcher, I observed and took field notes during several lessons at the beginning of year 8 in Natalie's, Kym's and Elizabeth's science classrooms. Each of their teachers appeared to be friendly and conscientious about teaching science. However, only in Elizabeth's classroom did I observe any attempts to place any of the practical work in a relevant context. One example was when students were asked to observe the effects of acid on various types of rocks. Each class did this activity, but Mr Giles was the only teacher who began the lesson with a discussion about acid rain, its causes and effects. Elizabeth's science class was hardly ever silent, and individual conversations between Mr Giles and his students were commonplace. His class was also the only one which ventured outside for activities, and only his students were encouraged to use their own style of taking notes and revising work.

> Mr Giles: What are you going to do to make yourself remember what the structure of the earth's like?
>
> Student 1: Um, read and take notes.
>
> Mr Giles: That might be a way.
>
> Student 2: Diagrams in colour.
>
> Mr Giles: Diagrams are good, colours are good.
>
> Student 3: Draw pictures.
>
> Mr Giles: Pictures are good.

Discussion

Every teacher seemed to be under constraints of the timetable, having to rush through activities, and having little opportunity for discussion at the end. The common content and assessment tasks being presented in each classroom made it difficult to be innovative or to adapt to the needs of particular students. Notwithstanding these constraints, Mr Giles managed to work within them and present a more activity-oriented and contextual curriculum in which the students could make choices, while at the same time developing a close relationship with his students. Elizabeth's experiences illustrate the means by which girls may be encouraged to enjoy science and to pursue career paths related to science. Her enthusiasm for, and confidence in her ability in science was nurtured by a high school science teacher whose pedagogy incorporated many of the strategies of an inclusive curriculum. Hands-on activities which had a real life context took place nearly every day in her science class. Student-led discussions on a wide variety of issues were commonplace. A relaxed attitude by the teacher, and the students' obvious appreciation of the supportive, non-competitive environment were features of Elizabeth's science classroom.

For Elizabeth, the close relationship which she developed with her science teacher, and the stimulating presentation of the curriculum were her main reasons for declaring science to be her favourite subject. This was in contrast to the experience of other students, such as Kym and Natalie, who felt isolated by the teaching strategies which were being used, and found their science teachers to be impersonal. The students whose teachers were using a less challenging approach and felt that their environment was less supportive in terms of their relationship with their teacher also provide evidence to endorse the suggestions by both the inclusivity and middle school literature.

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Student Generated Kinematics Graphs

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Abstract

A computer mediated approach to learning basic kinematics concepts based on recent educational research has been trialed at Edith Cowan University. Students are able to graph their motion in real time as they move in front of a sonic ranger device linked to a computer. Concepts of position, distance, velocity and acceleration are explored through these graphs.

The effectiveness of this approach is being investigated using pre- and post-testing as well as observation and interviews. How students interact with the technology and the affect of these interactions on learning outcomes is also being investigated. Preliminary results are presented in this paper.

Introduction

This project arose out of a desire to make the laboratory program for students undertaking the one semester "Foundations of Physics" unit in the Department of Applied Science at Edith Cowan University more exciting, modern and relevant to their needs. The first author had also witnessed the generally poor understanding of key motion concepts held by students both before and after instruction and was convinced that it was time to try a new approach to teaching these concepts. It was therefore decided to include computer based laboratory activities into the program to address both of these concerns.

The science education literature of the 1980s and 1990s includes numerous studies which show that many students come to instruction with existing conceptions about natural phenomena (Driver, 1989; Gilbert, Osborne & Fensham, 1982) which are inconsistent with the scientific conceptions students are expected to learn. These alternative frameworks interact in complex ways with instruction and the resulting learning outcomes are often misconceptions (Osborne & Wittrock, 1983). Posner, Strike, Hewson and Gertzog (1982) argued that if students are to reconstruct their existing alternative frameworks the learner would need to become dissatisfied with their existing conception and the new conception would need to be intelligible, plausible and fruitful. Other writers have proposed instructional strategies that can facilitate this conceptual accommodation (eg Driver & Oldham, 1986; Osborne & Freyberg, 1985). These strategies include the provision of opportunities for the students to make their conceptions explicit, experiences with situations which cause cognitive conflict between the alternative framework and experimental data, and opportunities to discuss, compare and apply ideas. Others have argued that interactions with peers or the teacher can scaffold the student's thinking through the zone of proximal development, that is, the difference between the student's current thinking and the next level of thinking (Vygotsky, 1978).

Previous research by Trowbridge and McDermott (1980) revealed that American college students completing introductory physics courses had difficulty comparing the motion of real objects and identifying when they had the same velocity. Many students associated "same speed" with "passing" or "same position" and did not have a concept of velocity involving a ratio of distance travelled and elapsed time. In a similar study of college students' understanding of acceleration Trowbridge and McDermott (1981) found that even after instruction fewer than half of the students demonstrated a sufficient qualitative understanding of acceleration as a ratio ($\Delta v/\Delta t$) to be able to apply the concept in a real situation. Students also experience difficulty in interpreting position-time graphs confusing the height of the line rather than the slope for velocity, and difficulty in sketching 'qualitative' graphs to represent the acceleration of objects (McDermott, Rosenquist & van Zee, 1987).

Thornton and Sokoloff (1990) reported much success in teaching these concepts in the laboratory using an ultrasonic motion sensor connected to a computer with fast graphing capabilities. Students walk in front of a motion sensor (which works like a radar, but using ultrasound) connected to a computer which can plot in real time the student's distance (in front of the sensor), velocity and acceleration as functions of time. They were also asked to match pre-programmed motion graphs on the computer screen with their own motion and this was seen as a particularly useful tool. There was a significant improvement in students' understanding of motion graphs measured using identical pre- and post-tests.

This computer based laboratory activity has the potential to help make explicit students existing conceptions of velocity and acceleration and create cognitive conflict between those conceptions and the immediate feedback provided by the computer. It was decided therefore to study introductory physics students' interactions with this program and explore its potential for facilitating the accommodation of students alternative frameworks. More specifically the study addressed the following research questions:

- How do students interact with the technology and with each other and the laboratory demonstrator in this computer mediated learning environment?
- To what extent are students alternative frameworks made explicit, cognitive conflict created between conceptions and data, and conceptual accommodation occur?

Method

The participants were students in the SCP1122 Foundations of Physics unit at Edith Cowan University in second semester of 1996. This unit assumes no previous knowledge of TEE Physics. Motion concepts had been covered in the traditional way through lectures in the week preceding the laboratory classes. Students in three of the five laboratory classes participated in the computer assisted experiment using the ultrasonic motion sensor. Their main tasks were to:

- Activity 1: Produce and analyse distance-time and velocity-time graphs of their motion.
- Activity 2a: Match a pre-programmed distance-time graph with their motion (zero acceleration)
- Activity 2b: Match a pre-programmed velocity-time graph with their motion (zero acceleration)
- Activity 3: Predict a distance-time and velocity-time graph for a described motion
- Activity 4: Produce and analyse velocity-time and acceleration-time graphs of their motion
- Activity 5: Match two pre-programmed velocity-time graphs (uniform acceleration)

Students in the other two laboratory classes conducted a more traditional experiment using ticker timers.

All students were given pencil and paper pre- and post-tests with an emphasis on the interpretation of velocity graphs. The pre- and post-tests were identical and students were allocated up to 15 minutes to complete the tests leaving approximately 90 minutes for experimental work.

Students were given written instructions for the experiment immediately following their completion of the pre-test. Several minutes were allocated to demonstrate the motion sensor and computer software before students were split into groups of three. One group was videotaped from each of the three laboratory classes doing this experiment. The first group (group C - all male) selected themselves by choosing the equipment being videotaped, the second group (group B - all female) was selected to provide some gender balance and the third group (group A - all male) were selected as they were identified by their demonstrator as being a vocal group (we perceived our previous two groups to be very quiet). About 20 minutes from the end of the laboratory session these videotaped groups were debriefed with a standard set of questions before completing the post-test with all the other students.

Preliminary Results and Discussion

The results from the pencil and paper pre- and post-tests for the nine students who were videotaped are summarised in Table 1.

Table 1.

Mean pre- and post-test scores, and percentage change for the students who were videotaped while working on the computer based motion activity (n=9)

Question	Maximum possible score	Mean pre-test score	Mean post-test score	Percentage change
Interpretation of motion from a velocity graph (free response)	8	5.0	5.8	+16
Sketch of acceleration graph from a velocity graph	5	1.1	2.3	+110
Concept of velocity (free response)	2	1.1	1.6	+40
Concept of acceleration (free response)	3	1.1	1.8	+60
Interpretation of velocity graphs (multiple choice) from Thornton & Sokoloff (1990)	5	3.2	4.3	+34
TOTAL	23	11.6	15.8	+37

On all questions, the mean student score improved after conducting this experiment. The most dramatic improvement appears to be in the two questions involving acceleration; possible reasons for this and other trends are still the subject of investigation.

This paper is mainly concerned with students' interpretation of (constant) velocity graphs and in particular how two groups are learning the relevant concepts through activity 2b: where students match a pre-programmed velocity vs time graph for the first time. The graph being matched and a typical student attempt (as seen in both groups) is shown in Figure 1. Students had previously successfully matched a distance time graph which necessitated moving both away and towards the motion sensor. The positive direction is away from the motion sensor.

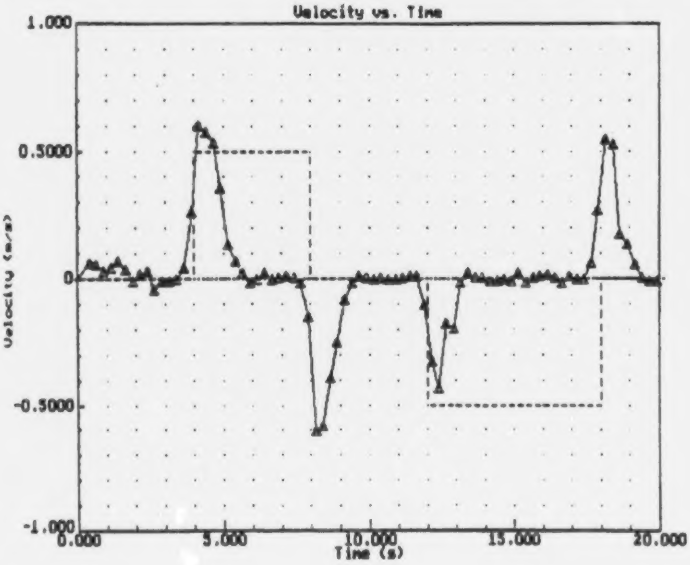

Figure 1. A typical student attempt (triangles) at matching the pre-programmed velocity vs time graph (dashed line) in activity 2b.

Group A had five attempts at matching this graph. Each attempt resulted in a greater understanding. One student was particularly vocal and undertook a leading role throughout this activity and will be referred to in this paper as the "leading student". In the first attempt, the student moved towards the motion sensor instead of away from the sensor for the positive velocity. There was discussion amongst the students about whether to move away or towards, forwards or back (students are always facing the motion sensor). The terms positive and negative direction were never used. After this attempt the students wanted to try again.

Leading student: lets do that one again.
Other student: move backwards?
Leading student: Yeah, when it goes up that means you're moving away from it (sic: motion sensor)

In the second attempt, the students misinterpreted the vertical and horizontal lines on the velocity graph to produce a graph similar to that shown in Figure 1. The vertical lines were interpreted as meaning "move" and the horizontal lines are interpreted as meaning "stay still". In addition, upward vertical lines (at 4 and 18 seconds) are interpreted as meaning "move away" and the downward vertical lines (at 8 and 12 seconds) are interpreted as "move towards". At the 4 second mark which corresponds to the first vertical line, the subject is encouraged by his peers to go backwards and then stay still.

Leading student: Backwards....yeah......stay, no you've got to stay still.

But the subject is staying still and his velocity stays at zero rather than 0.5m/s.

A similar situation arose when he was supposed to move towards the sensor at 0.5m/s. He moved at the 12 second mark and then stopped and his corresponding motion was seen to move from -0.5m/s to zero, leading to the following conversation:

Exasperated student: How do you get it along there? (pointing towards horizontal line at -0.5m/s)

Leading student: I'll show you.

Pause

Exasperated student: How do you get it to stay there?

In the third attempt, the leading student demonstrates an understanding that the horizontal line at 0.5m/s means that he must move backwards at constant velocity. The exasperated student is able to work this out as he watches this motion and the corresponding graph.

Exasperated student: See, how do you keep it like that..........Oh, you keep at constant velocity moving back!

In the fourth attempt, the group discovered another problem.

Student: The problem is you've got to move forward all the time and you run out of space.

Leading student: I ran out of space.

The group realise that for the fifth and final attempt they must start further back.

In summary, the matching graph activity created a mismatch between the graph to be matched and their conception of how they should move to match the graph. The students in group A needed to relate the observed motion and corresponding graph with their existing knowledge structures, reflect critically and accommodate. One student in this group was able to do this and scaffold the activity for the other group members so that they could understand the operational meaning of the horizontal and vertical lines on the velocity graph.

Group B had many attempts at matching this graph. Like group A, the activity created cognitive conflict for all students, but unlike group A, this group was not able to resolve the conflict without intervention from the demonstrator.

The region between 4 and 8 seconds on the graph was interpreted by one group member as

Student: Go really fast, then stop, and go really quick back!

The corresponding first attempt mirrors these instructions leading to a graph similar to that shown in Figure 1. The students were somewhat bewildered:

Student 1 So what's going on there?

Student 2 Oh...no way!

They showed in their next attempt that they could not interpret this graph yet they were happy to move on to the next activity until the demonstrator intervened:

Demonstrator: How are you going?

Student: Done that one

Demonstrator: Done that one?

Student: Yes

Demonstrator: Oh...I don't know? (laughter)

The group had another six attempts and the demonstrator returned when it was obvious that were not going to be able to solve the problem without help. With prompting, the students could read the velocity on the provided graph as 0.5m/s at different times between 4 and 8 seconds and they decided that the velocity was constant in this region, but they still did not grasp what it meant to move at constant velocity:

Demonstrator: Can you see what you do.....to do that motion?

Student: You just have to step back half a metre and stop there........would that do it?

Demonstrator: Or....half a metre every second. Every second you have to move half a second, backwards

Demonstrator: What happens if you stop?

Student: Going to go back to zero, there (pointing to horizontal time axis)

Demonstrator: And if you're up there (pointing to 0.5m/s horizontal line between 4s and 8s)?

Student: You've got to stay constant

Student: You've just got to get at constant speed on those.

Demonstrator: Yes basically....that's exactly right

In the following, and final attempt, the group demonstrated that they understood that they needed to move at constant speed for the horizontal lines. In summary, the matching graph activity created a cognitive conflict which the students were not able to resolve by themselves. The demonstrator was required to scaffold the task for students in group B in order to facilitate learning.

Conclusions

The preliminary analysis of data presented in this paper confirms the potential of this type of laboratory activity reported by Thornton and Sokoloff (1990), for helping students accommodate their alternative conceptions of velocity and acceleration. Students' attempts to move in front of the motion sensor and match the graph on the computer does create cognitive conflict which in turn stimulates important interactions between the group members. For one group reported here these interactions led to resolution of the conflict, whereas in the other group, intervention by the demonstrator was necessary to scaffold the thinking of the students leading to resolution of the problem. Further analysis of the data regarding the nature of the interactions between the students and the computer will be necessary to explain the improved responses to the post-test questions regarding acceleration.

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The Development of a Successful Industry-Education Partnership

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Abstract

This paper describes the development of the RGC Wetlands Education Centre in the South-west of Western Australia by RGC Mineral Sands in conjunction with the Science Teachers' Association of Western Australia. The purpose of the Centre is to facilitate an educational program for primary and secondary school students.

The three key components of the project are the development of a resource package specially designed to assist students and their teachers learn about the Wetlands, a school visits program, and a professional development program for teachers. The project offers students the opportunity to study and monitor the wetlands, thus creating an awareness of conservation and land management issues.

To date, more than 1000 students have benefited from the project and the material developed has been successfully trialed. The three components of the project are described and suggestions made for how key facets of the project may be transferred for use with students in other educational settings and wetlands areas.

The Site

The RGC Wetlands Centre is situated at Capel, 200 km south of Perth, Western Australia. It is composed of a chain of 15 lakes created from mining pits left after the extraction of mineral sands. The lakes cover approximately 50 ha of a total of 350 ha and are around two metres deep. Presently, the lakes are fed by treated water from the processing plant and some are interconnected.

Before to mining, the area was a pine plantation and a banksia woodland. Mining took place between 1976 and 1981. From 1981 to 1986, the pasture around the lakes was grazed by cattle while the planning of the new wetlands was undertaken.

In 1985, a committee was convened to oversee the development of the site. The RGC Wetlands Centre Management Committee drew representatives from RGC, the Royal Australasian Ornithologists Union (RAOU), UWA, Murdoch University, Curtin University of Technology, the department of Conservation and Land Management and, in 1993, the Science Teachers' Association of WA. The Education Manager and STAWA's Executive Officer attend all Wetlands Centre Management Committee meetings.

Since then, a development program has been in place. This incorporates the creation of a wide range of habitats to encourage numerous species of animals and the installation of facilities for visitors such as paths, hides and educational support materials including an Eco-centre classroom. Development has been planned so that each lake retains much of its own character and landscape. Tree and species selection, island and spit construction, and hay and branch additions are techniques that have been used to attract waterbirds and make each lake a unique environment.

The objectives of the RGC Wetlands Centre are:

1. To develop a self sustaining wetland ecosystem for the conservation of waterbirds, on lakes created by mining at Capel;
2. To facilitate research into wetlands ecosystems, including their development and management;

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3. To develop facilities for public education and recreation at the Capel wetlands; and
4. To develop and demonstrate rehabilitation technology for wetlands created by human activities.

The Educational Program

The third objective above addresses the role the RGC Wetlands Centre has in providing the community with the opportunity to study and learn about wetlands environments. In 1992, RGC Mineral Sands expressed an interest in developing the educational potential of its Wetlands Centre. In 1993, STAWA was invited to take on the role of educational consultant and manager of the wetlands educational program. A part-time Education Manager was appointed. Since this appointment, an educational resource package has been produced, teachers have undertaken professional development at the Wetlands Centre and school groups now visit the Centre on a regular basis.

The initial STAWA management plan for the educational aspect of the RGC Wetlands project included the following aims:

1. To give the Wetlands management considered advice about the effects of physical development on the Wetlands' educational potential;
2. To develop suitable quality teaching resource materials for relevant primary and secondary school syllabuses;
3. To make all WA teachers aware of the educational potential of the RGC Wetlands;
4. To develop suitable quality educational material aimed at the general public; and
5. To store and distribute the educational materials developed by this program.

STAWA has its own committee that monitors the educational aspects of the RGC Wetlands Centre project. The Capel Wetlands Education Advisory Group (CWEAG) comprises a selection of teachers interested in the educational program being developed at the Wetlands. CWEAG members provide recommendations on curriculum and infrastructure development and generally support the program.

The purpose of this paper is to describe fully the educative function and practice of the Wetlands Centre. The following issues are addressed:

1. The development of a resource package—titled *From Sand to Ducks*—specially designed to assist students and their teachers learn about the Wetlands;
2. A school visits program involving students from both the primary and secondary levels of schooling; and
3. A professional development program for teachers.

The Resource Package

To gain maximum advantage from school visits to the Wetlands Centre, it is important that students have access to relevant learning materials of a high quality. The purpose of these materials is to guide teachers' decision-making processes and to facilitate student learning. The materials can be used also to provide pre-learning in preparation for a site visit, to structure on-site activities, and direct follow-up activities in which students apply new knowledge gained from a field trip to new and interesting situations. It is possible also, that materials developed to support one geographic location may be used by teachers and students at other locations. This generalisability aspect, while an added advantage in this instance, was not a priority influencing the design of these materials.

The material which now comprises the package *From Sand to Ducks* targets primary and lower secondary students. It contains a wide variety of site-related practical activities which promote environmental awareness. It is a loose leafed file comprising photocopyable worksheets and background information for both teachers and students.

Collection of data to be used in this package started in 1993. It was necessary to acquire a knowledge of the area and the flora and fauna before any writing could commence. The package was written with the assistance of on-site staff from the RGC Wetlands Centre and consulting scientists who formed part of the RGC Wetlands Centre Management Committee.

The resource package, comprising over 150 pages, contains the following sections: (1) General Information, (2) Introductory Activities, (3) Plants, (4) Aquatics, (5) Frogs, (6) Reptiles, (7) Birds and (8) Post-visit Ideas and References.

Teachers choose the appropriate activities and then photocopy the material for their students. The activities have been trialed at the site with school groups and the overall aim of the package was for it to be practical and simple to understand. A summary at the front of the file indicates the year levels for which each activity is suitable. A brief description of the components of the package is provided below. A more detailed description of the package's contents can be found elsewhere (Thiele & Donnelly, 1996).

The *General Information* chapter provides information for teachers about the history of the RGC Wetlands Centre, information about how to arrange a school visit to the Wetlands Centre, and it provides samples of programs for full- and part-day visits to the wetlands. The chapter also includes a pro-forma Visit Permission Note and an Educational Activities Booking Form. The educational activities available at the wetlands are briefly described in this chapter.

The *Introductory Activities* chapter aims to make students more aware of their surroundings and the living things in them. It encourages them to use all their senses to make useful observations. The chapter includes several practical activities including *Where Have You Been?*, *Biologists for a Day*, and *Looking at a Lake*.

The *Plants* chapter is the largest in the package due to the extensive plant identification keys provided in the package. The diversity of flora and habitats make it possible for students to participate in a variety of plant-related activities. The chapter contains three activities that engage small groups of students in locating, observing and naming plants. There are also activities introducing students to the concept of rehabilitation and encouraging them to develop their senses of sight and touch with an emphasis on flora.

The *Aquatics* chapter is the first of four that relate to animal life in the wetlands. The activities involve students in the use of dip nets to capture and observe aquatic animals, to use simple microscopy to observe water and mud samples from various sites around the wetlands, and in measuring pH and applying this knowledge to water samples.

The *Frogs* chapter is one of the more significant of the animals sections. *Finding Out About Frogs* is a pre-visit activity in which students use their own knowledge plus other resource materials to complete an excursion chart about frogs. *Catching and Identifying Frogs* involves the use of a specially designed dichotomous key and students make observations about frog habitats in *Frog Hollows*. The final activity in this chapter is *Trapping Frogs*. The activity introduces students to pitfall traps and the history and theory of pitfall use is described.

An activity about *Reptiles* is provided in the small chapter of that name. In doing *Reptile Report*, students learn about pitfall traps and making scientific observations. From this they learn the characteristics that all reptiles possess.

The *Birds* chapter, which is the last thematic section in *From Sand to Ducks*, contains a useful amount of teacher background information about bird species found at the Wetlands. The chapter's first activity, *Bird Watching at McCarley's Swamp*, involves the use of binoculars and telescopes to view and identify birds. The *Bird Hide* makes use of a large on-site bird hide that can accommodate a whole class simultaneously. Older students appreciate the chance to engage in *Mist-netting for Bush Birds*, an activity that usually takes place early in the morning.

The final chapter of the package includes *Post-visit Ideas* and *References*. Here, the activities listed are linked to other wetlands sites and a bibliography of literature and technical reports about the RGC (and other) Wetlands Centres is listed.

A supplementary set of activities, designed principally for secondary biology studies, is presently being edited. This will be added to the file by teachers of secondary students. A Teachers' Writing Weekend was held in 1995 where four Biology teachers helped create some of the activities in the supplementary package. The completion of these secondary materials will mark the culmination of four years' work in drafting, trialing, editing and publishing the package which has become integral to the activities of both school visits and the teacher professional development workshops that are discussed in detail below.

School Visits

School groups started visiting the RGC Wetlands Centre in 1994. Since then, more than 30 groups per year have visited the RGC Wetlands Centre to participate in educational activities.

While the first visits were used to trial the material which was produced for *From Sand to Ducks*, it was necessary for certain infrastructure to be on-site to support these visits. Hence, a number of educational facilities have been built by RGC since 1993. These include walk trails, board walks, a large bird hide, a classroom and storage area, and a toilet block. The area where many of the school activities are found is around Paperbark Lake; this is where most of the facilities are located. The other parts of the Wetlands are used to a lesser extent and this use is dependent on the aims and interests of the visiting school groups.

It was first thought that the worksheets in *From Sand to Ducks* may have been able to stand alone and not require additional input from a teacher employed on site. However, teachers' knowledge bases often do not extend to the biological aspects of the Wetlands. Subsequently, the teachers were not prepared to visit unless they had support in the form of experienced personnel. It was a decision of the management of the

Centre to provide substantive and in-kind support for the Project Manager, Tour Guide and Education Manager to assist school groups visit the Wetlands Centre.

While at the Wetlands Centre, students engage in activities from the resource package described above. Activities popular with students include netting for birds, comparison of water birds and habitats, dip-netting, microscopy, frog, reptile and plant identification, water chemistry measurement, art activities, and food chains and web activities.

Visitation records indicate that the most frequent visitors to the Wetlands Centre are primary schools that are located less than 50 km from the site. It could be argued that travel costs and the inflexibility of high school timetables act to inhibit greater visitation to the Wetlands.

The timing of students' visits to the Wetlands Centre depends upon several key factors. The climate of the South-west of WA is hot and dry in summer. Therefore, these months are not popular for school visits. In addition, it takes time for teachers to organise their programs and to become sufficiently familiar with their students so that they feel comfortable taking them on a site visit. Therefore, more school visits occur in the latter part of the year.

More primary groups visit than secondary. It is far easier to take a primary group out of school because it does not usually cause disruption to the rest of the school or teachers. In primary schools, one teacher is responsible for most of the education program for a class. In contrast, if a secondary class or a teacher is absent for a day there is disruption to the other classes taught by that teacher and to the other lessons normally attended by the students.

More local schools visit than any other group. It takes about twenty minutes to travel to Capel from the large neighbouring towns of Busselton and Bunbury so the time factor and the cost of bus hire influence the groups that visit.

Participation in activities

Most local school groups visit once in a year although there are usually a few classes that attend more frequently. If a primary group is making only one visit they are given a sample of the Wetlands' activities. The day's program might include:

1. An introduction to, and short history of, the Wetlands;
2. Environmental awareness activities;
3. A plant activity such as using maps to find tagged plants and either making observations of these or identifying them depending on the skills of the students;
4. A visit to the bird hide; and
5. Dip netting and identification of aquatic animals.

Other popular activities include:

1. Mist netting, identification and banding of birds (usually reserved for small groups and Years 11 and 12 Biology students);
2. Frog studies (identification, frog hollows);
3. Walk trail; and
4. Tree planting/rehabilitation.

If a school group comes on a number of visits in a year then a different theme is usually chosen for each visit.

Teacher Professional Development

It is important that teachers are made fully aware of the Wetlands Centre and the educational opportunities available. To ensure that this happens, STAWA promotes teacher professional development at the Centre.

The teacher professional development courses that are offered assist teachers:

1. To become aware of the RGC Wetlands Centre as a resource for studying the rehabilitation/creation of a habitat;
2. To study the environmental factors, both living and non-living, of wetlands ecosystems;
3. To use plant and animal identification keys and information sheets which have been developed for this wetland ecosystem; and
4. To determine the suitability of different activities for particular student groups during a visit to this Wetlands Centre.

Eight teacher professional development courses have been run since 1993 with a total of 69 teachers attending. Seven of these courses were held on weekends while one was a one-day course which proved popular with local teachers. Six enrolments is considered to be the minimum number for a viable course—any less and the course is usually cancelled. All courses are now offered to both primary and secondary teachers rather than separating the groups. This allows for more interaction and gives more of a chance of making up the required numbers.

The RAOU Project Manager and RGC's Tour Guide run these courses with the Centre's Education Manager. Weekend courses involve activities such as a mineral sands mine tour, mist netting, dip netting for aquatic animals, plant identification, rehabilitation and visiting the research sites. The groups also spend some time with a representative from the department of Conservation and Land Management (CALM) spotlighting for possums, observing birds on the nearby Wonnerup estuary and trying various trapping techniques.

The RGC component of the course takes place at the Wetlands Centre and the CALM component occurs in and around the Tuart Forest at Ludlow. This is an old mill site and residential area between Capel and Busselton where the CALM employees lived. Some still live there but it may be turned into a camp site for people wishing to explore the area in the future. A school room is available for visiting groups.

Teachers from local schools, other south-west towns, and from Perth have attended the courses. Some Perth teachers have brought their students back to camp and participate in activities at Ludlow and the Wetlands Centre and a few groups now visit annually.

Teachers' awareness of the RGC Wetlands Centre and its role as an educational resource has been raised in a number of ways:

1. Each semester, the weekend teacher professional development courses are advertised to all WA schools through STAWA's PD Booklet.

2. Flyers are sent to local schools advertising the weekend and one day courses.
3. Information about the Wetlands Centre is sent to local schools
4. In 1995 and 1996, displays were set up at the annual secondary science teachers' conference (CONSTAWA). The Education Manager attends these conferences to provide information for teachers and answer questions about the Wetlands.
5. Information was provided to attendees at the 1996 primary science teachers' conference (PRISSEM).
6. The Education Manager has many contacts in the local schools and uses these to promote the Wetlands.
7. "Word of mouth" - positive comments from teachers who have visited the Wetlands and attended professional development courses have encouraged other teachers to attend.
8. The production and launching of the resource package has given the Wetlands Centre a higher profile and educational standing.

Conclusion

The educational program offered to both teachers and students is fulfilling the original aims of the project. Some teachers are making a visit to the Wetlands Centre an annual event. Interest in the Centre is spreading as more people become aware of the variety of student-centred activities available. The presence of the educational support with school visits has contributed to the increasing use of, and interest in, this educational facility. Teachers who visit the Centre with their classes are very positive about the activities and support offered.

The number of groups visiting the centre is expected to maintain its current level and possibly increase as long as the support structure is present.

Note

Copies of the resource package (*From Sand to Ducks)* may be obtained from STAWA.

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The Primary Science Teacher-Leader Project: What Have We Learned?

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Introduction

The Primary Science Teacher-Leader Project was conducted during 1995 and 1996 as part of the Education Department of Western Australia's Science Project - a four year initiative to improve the quality of science teaching and learning in Western Australian government schools. The overall goals of the Science Project are to:

- provide all schools with access to exemplary curriculum materials;
- establish an effective, whole school curriculum in primary schools;
- establish science teaching methodology in primary and secondary schools which is consistent with identified best practice;
- provide access for teachers to update their knowledge of science and its role in society; and
- establish networks of curriculum leaders to provide ongoing support for teachers.

The Primary Science Teacher-Leader Project - designed to address several of the overall goals - was conducted in two sections in 1996. These were the ongoing training of the 1995 primary teacher-leaders in 1996 and the training of the new primary teacher-leaders for 1996. Each district in the state was invited to fill one position in each section. Where the 1995 leader did not continue, the district was offered two positions for the 1996 Primary Teacher-Leader Project. At district level, teacher-leaders were asked to work with their district offices to plan and implement a science support program for local teachers. These local support programs were funded by the project, the level of financial support being between $12 000 and $16 000 per district. Selection of the personnel to attend the training program resulted in several teacher-leaders being based in district offices while others were school based. Five additional leaders were included in the 1996 project, each with specific expertise in one of the following areas: early childhood education; English as a second language; education support Aboriginal education and isolated and distant education. The 1995 teacher-leaders participated in a total of four days training. The 1996 teacher-leaders participated in a total of nine days training. This paper summarises the evaluation of the Primary Science Teacher-Leader Project in 1996 and focuses on the following issues:

- professional development of teacher-leaders with regard to primary science teaching methodology, theory, outcome based learning and leadership,
- networks established among 1995 and 1996 teacher-leaders and school coordinators,
- district level activity of teacher-leaders,
- school support provided by teacher-leaders and
- hurdles faced by teacher-leaders when implementing a program in their district.

Method

The researchers undertook four data collection phases. In each of the phases a combination of data collection methods were used to triangulate at the data collection level in order to enhance the dependability of the findings (Guba & Lincoln, 1989; Patton, 1990). The first phase of the evaluation was a review of the training program. The researchers attended meetings of the Primary Science Teacher-Leader training program and data collection included observation of a range of course activities and semi-structured interviews (Hitchcock & Hughes, 1989) with five representative teacher-leaders from the 1995 group and five representative leaders from the 1996 group. The second phase consisted of a questionnaire conducted with 44 of the 65 teacher-leaders. The questionnaire was designed after consideration of the issues included in the evaluation brief and other issues which emerged from the interviews with the representative teacher-leaders in Phase 1. Respondents were asked to respond to items on a five point Likert scale (Wiersma, 1986). Several open-ended questions also were included on the questionnaire. Responses to the items on the questionnaire are presented in Table 1.

The third phase of the evaluation was conducted as case studies in five representative districts. The purpose of the case studies was to identify and describe the activity which was happening at the district level, in schools and the activity occurring in classrooms which could be attributed to the Primary Science Teacher-Leader Project. Data collection included observation of network meetings and professional development workshops, interviews with the district teacher-leaders, interviews with four or five other teachers from each district and at least one school visit. Case study 5 is presented in the findings section of this paper. The final phase of the evaluation was a validation phase, the purpose of which was to validate the results of the questionnaire and the case studies. The results of the questionnaire were presented to the 1996 group of teacher-leaders and the case studies were returned to the leaders of the districts in which they were conducted. The comments and suggestions from the leaders about the questionnaire results and from the case study district leaders were recorded and taken into consideration in the final report preparation phase.

Case Study Findings: Marble District

Background

Donna was the Science Coordinator for this metropolitan district in 1995 and has continued in this role in 1996. Donna is a classroom based teacher-leader and has been joined by Alex, another classroom based teacher-leader, this year. The district teacher-leaders have cooperated with two other districts as a cluster to organise many of the activities they planned for the Primary Science Project.

What's Happening at the District Level?

Science professional development conference at Rottnest Island Donna and Alex, the district teacher-leaders, were very active in their role in 1996. There were a range of activities carried out through the year in order to support schools and teachers with regard to curriculum establishment, science teaching, and raising the awareness of science. The most visible of these activities was a science professional

Table 1

Results from questionnaire administered to Teacher-Leaders

Scale Scores

5 - strongly agree 4 - agree 3 - neutral 2 - disagree 1 - strongly disagree

No.	Question	Mean (n=45)	St Dev
	Training Program		
6.	The program has provided me with adequate theoretical background on teaching science for my role as teacher leader.	3.70	1.00
7.	The program has improved my knowledge of teaching methodology in science education.	4.16	0.68
8.	As a result of the program I am a more effective teacher of primary science.	4.14	0.85
9.	I am part of an effective network of science teacher-leaders as a result of the program.	4.34	0.86
10.	The program has lead to a change in my understanding of outcome-based learning in science.	4.30	0.79
11.	The program has complemented and supported the First Steps project. How?	3.43	0.85
12.	The program has improved my knowledge of how to be an effective teacher-leader.	4.09	0.91
13.	My role as science teacher-leader is clear to me.	3.96	1.06
14.	The division of the teacher-leaders into 1995 and 1996 leaders was appropriate for the training program.	4.00	0.91
	District		
15.	The profile of science in my district has been raised this year?	4.22	0.97
16.	A successful support network for science coordinators has been established in my district.	3.69	1.06
17.	I have provided support to primary schools in my district this year. What are the three most effective ways you have been able to do this ?	3.80	1.13
18.	The teacher-leaders in my district have worked effectively as a team this year.	3.92	1.19
19.	The district office has been cooperative with me in my role as science teacher-leader.	4.10	1.02
20.	The school administrators in the district have been cooperative with me.	3.67	0.80
21.	The school science coordinators have been supportive of the activities which have been organised in my district.	4.10	0.82
22.	The school science coordinators in my district have effectively carried out their role in their schools.	3.59	0.72
23.	The schools in my district have actively participated in activities organised as part of the Science Project.	3.85	0.99
24.	It has been beneficial to have more than one leader in my district.	4.08	1.06
25.	Communication with school coordinators has been a problem for me.	3.05	1.00
26.	More teachers are teaching science in my district as a result of the Science Project.	3.61	0.77
27.	As a result of the Primary Science Teacher-Leader Project teachers are teaching science more often in my district.	3.50	0.72
28.	As a result of the Primary Science Teacher-Leader Project the quality of primary science teaching has improved in my district.	3.62	0.70
29.	Primary school students in my district are participating in more science as a result of the Science Project.	3.85	0.74
	Other Issues		
30.	I have had enough time to complete the tasks I planned to do as a district teacher-leader.	2.36	1.20
31.	The new Education Department's professional development guidelines have enabled the Science Project to operate effectively in my district.	1.84	1.18
32.	Funding has been adequate to allow for effective teacher professional development.	3.12	1.13
33.	I have had adequate funding to complete the tasks I planned as district teacher-leader.	3.57	0.94

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development conference at Rottnest Island at which school coordinators from three districts in the cluster attended. The person from each school who attended the Rottnest conference was asked to share the knowledge, networking, skills, ideas and experience gained from the weekend with their staff on return to their schools. These same people were asked also to regularly attend district network meetings. Rottnest was chosen as a venue for the conference because the teacher-leaders felt it would be conducive to the development of collegiate support in a focused environment and it would focus the participants for the duration of the course. Donna and Alex felt the location would ensure a captive audience night and day and this would encourage more productive time on networking and professional development. They felt the trip away to Rottnest would reward the school coordinators for their commitment to science, recognise the coordinators as professionals and encourage long term commitment from them.

The conference was held on a Friday and Saturday in the middle of August and all travel to Rottnest Island, accommodation and meals were funded through the Science Project. Teacher relief was available for one person from each school for the Friday. The teacher-leaders felt this was a cost effective two days networking and professional development for one day teacher relief. The agenda at the Rottnest conference included an environmental walk, discussion of science tabloid days and science challenge activities, a science quiz night, and workshops on best practice and a range of ways to approach science, integrating technology and science and open ended investigations and links to student outcome statements. Time also was set aside for discussion of the district needs, how the coordinators can help their schools and how the coordinators can share their Rottnest conference experiences with their school. The Rottnest conference was generally felt to be an excellent forum for professional development by the teacher-leaders, and the school coordinators who attended. Not only was the professional development thought to be excellent, strong network bonds were established and the coordinators said they had a lot of fun too.

Network meetings. The coordinator's network meetings held on a once a term basis in this district have been a successful forum for the dissemination and sharing of information on science education and as a mode of feedback and communication between the school coordinators and Donna and Alex. For example it was established at the Rottnest conference that extension and enrichment of the activities in the Primary Investigations program was a high priority. This was subsequently included on the agenda for the network meeting held in early September. Other network meeting activities have included an overview of the Science Project, discussion of the district strategic plan, Rottnest conference feedback, newsletter discussion and workshops on science collaborative learning and Primary Investigations extension and enrichment. The network meetings also have included the display and presentation of a wide range of science resources.

Newsletter. The teacher-leaders are currently working to establish a science newsletter in the district as another form of communication other than the coordinators network meetings. At the network meeting in term three the coordinators agreed that a newsletter would be a good avenue for the school coordinators to share science information and extension activities with other schools and that all the school coordinators could submit articles to the teacher-leaders for the newsletter. It was decided that it would be useful to have a newsletter once a term, in-between coordinators network meetings.

Pre-Primary Science. A need for support for pre-primary teachers in the district trying to establish science in their classrooms was identified by Donna and Alex through feedback from the school coordinators. Primary Investigations does not include a pre-primary program and this means many pre-primary teachers feel excluded from the whole school programs being established. The district coordinator's network meeting in term three included a session on enrichment and extension of Primary Investigations and during the session the six pre-primary teachers present were grouped together so they could address their special needs. Since their successful meeting at the term three coordinators meeting some of the pre-primary teachers have established their own science network and are planning to develop more comprehensive pre-primary science teaching materials.

What's Happening at the School and Level and in the Classrooms?

Many of the schools in the district have introduced Primary Investigations or another whole school program. For example at *Callistemon Primary School* where *Iris* is the school coordinator Primary Investigations was introduced at the beginning of third term 1996. Many of the teachers at the school already had a science program for the class, however those who didn't have found Primary Investigations to be very useful. Those teachers who already had their own program have found Primary Investigations to be somewhat restrictive and prescriptive, however, Iris has been involved in helping those teachers to use Primary Investigations as a starting point and to use their own lessons to extend and integrate with other areas such as art and language. The school has yet to have any Primary Investigations training, however, Iris is currently organising this with the project leader.

Sophie is the science coordinator at *Grevillia Primary School* where Primary Investigations was initiated in 1995. All the 1995 teachers received Primary Investigations training and the program became part of school policy. The problems the school has faced in 1996 with Primary Investigations is that many of the new teachers who came to the school at the beginning of the year have not had Primary Investigations training and Sophie spends much time helping these teachers and encouraging them to use Primary Investigations or in some cases it has been diplomatic for her to let the new teachers use their own program. For Sophie, the idea of on-going professional development in this area is necessary for these reasons.

Martin is a middle primary school teacher and has been using Primary Investigations as part of his whole school science program since early in 1995. He says that the investigations are much easier for him to use this year because it's his second time around. This year he has been involved in adapting the investigations to the needs of his students and trying to make the investigations more open ended and increasing the amount of integration with other areas of the curriculum. For example, last year Martin used an activity from Primary Investigations that involved the students in testing different kinds of washing powder by washing pieces of material that had been stained with cooling oil. The students found that the stains were removed regardless of the kind of washing powder used. Even if the material was simply washed in cold water the stain still disappeared. This year, after having professional development on open investigations, Martin hopes to improve the activity by allowing the students to experiment with several alternative stains such as grease, tomato sauce, texta, and ink. He also plans to integrate the activity into social studies and look at consumer science and advertising.

Discussion

Teacher-leaders agreed that the training program provided them with adequate theoretical background on teaching science for their role as teacher-leader (Table A, item 6). In addition, they believed that the training program has improved their knowledge of science teaching methodologies (Table A, item 7). The balance between theory and practical activities was well received. Valuable networks have been established amongst 1996 leaders and between 1996 and 1995 teacher-leaders (Table A, item 9, 14 & 24). The network system is particularly cohesive between district office based teacher-leaders.

Teacher-leaders felt that as a result of the program, they have an improved and updated understanding of outcome based learning and assessment (Table A, item 10) and are able to apply these ideas to the classroom. Case studies show that the professional development at the district level has given some coordinators more confidence with outcome based learning. The leaders agreed that the program has prepared them effectively for their leadership role and that the leaders have been working effectively as teams in the district (Table A, items 12, 18). Leaders said and case studies showed that the presence of more than one leader in districts has been beneficial (Table A, item 24). A few school based leaders were not clear of their role and felt ineffective because of time limitations and a sense of domination by the district office leader.

Leaders agreed that networks of school coordinators had been established in their districts and that school coordinators had supported the activities organised by the Primary Science Project in their district (Table A, items 16 & 21). Case studies and leaders' comments suggest that coordinators who attended district network meetings and participated in professional development effectively carried out their role of support in their schools. Concerns were raised by the leaders about non-participating schools.

There was a clear message from the teacher-leaders that they agreed or strongly agreed that the profile of science had been raised in their districts in 1996 (Table A, item 15). Leaders generally agreed that they had provided support to primary schools in their district (Table A, item 17). The biggest successes of the programs being implemented in the science districts were the professional development days and science conferences which utilised the one day teacher relief available. Other areas of success mentioned by the leaders included science competitions, network meetings and Primary Investigations training.

Focus group leaders reported that they found it difficult to get started because they didn't have a set amount of allocated money and they didn't have a designated group of teachers or a district to work with. However, as the year progressed and with the help of the Science Project leaders, the focus group leaders overcame some of their initial problems and were able to provide some support in their focus areas.

The leaders disagreed that the new Education Department's professional development guidelines have enabled the Science Project to operate effectively in the districts (Table A, item 31). This issue in conjunction with other restrictions on spending was mentioned by leaders as being the biggest hurdle for them in implementing the program in their district. Other hurdles included lack of time, especially from school based leaders (Table A, item 30); geographical distance, especially from country based leaders;

communication with school coordinators (Table A, item 25); lack of interest from some schools and the late start to the 1996 program.

Case study data indicated that school based leaders were generally very active in their own schools. The ways that leaders supported science in their schools included encouraging teachers to get involved in science professional development, establishing a whole school program, encouraging teachers to exercise professional judgement in extending and altering programs to suit their students, making arrangements for science equipment, and organising and implementing science competitions for students.

Conclusions

The 1996 Primary Science Teacher-Leader Project has successfully conducted a professional development program for a highly motivated and dedicated team of primary science teacher-leaders in 1996. The evaluation provided sound evidence that the project made progress on all of its goals. The dedication of the Science Project team has maintained the momentum of the Science Project from 1995 to 1996. This has resulted in a year where teachers have had access to relevant professional development and schools and teachers have been encouraged and supported in their endeavours to improve the teaching of science at the primary level.

The project has extended the professional development and maintained successful networks among those teacher-leaders who started their training in 1995 and continued in 1996. The 1995 and 1996 teacher-leaders have, in most cases, worked effectively as teams in their districts to strengthen the commitment to primary science education and share the workload of the science teacher-leader role. The teacher-leaders have been committed and proactive in their districts providing relevant professional development for classroom teachers, raising the profile of science, and providing support to schools and teachers. Schools, generally, have been supportive and active in participating in activities organised by the teacher-leaders at the district level. The teacher-leaders have expressed concern about the schools in the state that have not become involved in the Science Project. Other areas of concern about the Science Project expressed by the teacher-leaders include the restrictions on the ways that the teacher-leaders have been able to spend their funding, particularly on teacher relief, time constraints for school based leaders, and distance restrictions in remote areas of Western Australia.

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A Culturally Sensitive Learning Environment Instrument for Use in Science Classrooms: Development and Validation

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Abstract

Many students come from communities with widely differing cultural practices and thus, there is an increasing need for teachers to be sensitive to the important cultural milieu in which their teaching is placed . As schools are becoming increasingly diverse in their scope and clientele, any examination of the interaction of students' culturally sensitive learning environments with learning processes, assumes critical importance. The purpose of this exploratory study was to develop an instrument to assess these culturally sensitive learning environments, to provide initial validation information on the instrument and to examine associations between students' perceptions of their culturally sensitive learning environment and their attitudes towards science. A measure of science students' cultural factors that might affect learning, namely the Cultural Learning Environment Questionnaire (CLEQ), was developed from past learning environment instruments and was influenced by Hofstede's four dimensions of culture (Power Distance, Uncertainty Avoidance, Individualism and Masculinity/Femininity). The reliability and discriminant validity for each scale was obtained and associations between students' culturally sensitive learning environment and their attitudes were found. The homogeneity of perceived learning environments within classrooms was examined.

Introduction

While there are a number of research studies in science in existence concerning culture and education generally (Atwater, 1993, 1996; Cobern, in press; Maddock, 1981), comparatively little research examines the interaction that occurs between students' culturally sensitive learning environment and their learning processes. It is timely and relevant to examine how students' culturally sensitive learning environments enhance or inhibit their learning within a secondary school science classroom.

In this exploratory study, culture is defined as "the distinctive way of life of a group of people, their complete design for living" (Kluckhohn, 1951, p. 86). It is argued that at the macro-classroom level, there are distinctions that can be made between the preferred learning styles for different high school students. This article describes the development of a questionnaire to assess culturally sensitive learning environments and its application in investigating relationships between these culturally sensitive learning environments and students' preferred student-teacher interpersonal behaviour.

Assessing the Culturally Sensitive Learning Environment

In his research on human environment, Moos (1979) found that three general categories can be used in characterising diverse learning environments. This finding emerged from Moos' work in a variety of environments including hospital wards, school classrooms, prisons, military companies, university residences and work milieus. The three dimensions are: *relationship dimensions* which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other; *personal development* dimensions which assess personal growth and self-enhancement; and *system maintenance and system change* dimensions which involve the extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change.

In the past 25 years, Moos' work has influenced the development and use of instruments to assess the qualities of the classroom learning environment from the perspective of the student (Fraser, 1986, 1994; Fraser & Walberg, 1991). Examples of classroom environment instruments include: the *Learning Environment Inventory* (*LEI*) (Fraser, Anderson & Walberg, 1982) which measures student perceptions of 15 environment dimensions of secondary school classrooms; the *Classroom Environment Scale* (*CES*) (Moos & Trickett, 1987) which contains nine scales for use in secondary school classrooms; the *My Class Inventory (MCI)* (Fraser, Anderson &.Walberg, 1982) which is suitable for use with children in the 8-to-12 years age range; and the *College and University Classroom Environment Inventory (CUCEI)* (Fraser, Treagust & Dennis, 1986) which is suitable for use in tertiary education settings. Other more specialised instruments include: the *Individualised Classroom Environment Questionnaire (ICEQ)* (Fraser, 1990) which assesses those dimensions which distinguish individualised classrooms from conventional ones; the *Science Laboratory Environment Inventory (SLEI)* (McRobbie & Fraser, 1993) suitable for assessing the environment of science laboratory classes at the senior secondary or tertiary levels; and the *Constructivist Learning Environment Survey (CLES)* (Taylor, Dawson & Fraser, 1995) designed to assist researchers and teachers assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology. As the scales of all of these instruments can be categorised into one of the dimensions of Moos's scheme for classifying human environments referred to above, there is some commonality in the conceptual frameworks underpinning the assessment of classroom environment. It was thus determined that any instrument used in this study would also be based on Moos' dimensions.

However, none of the instruments referred to above were designed specifically to be culturally sensitve to the student's learning environment and it was necessary to devise a new instrument. The new culturally sensitive learning environment instrument utilised in this study was based on previous learning environment scales that a review of research literature indicated could be culturally important. The selection of these scales was guided by the fields of anthropology, sociology, management theory and Hofstede's (1984) dimensions of culture. After collecting information with a detailed questionnaire from thousands of individuals working in multi-national corporations operating in 40 countries, Hofstede (1984) analysed the data and identified four dimensions of culture, namely, *Power Distance, Uncertainty Avoidance, Individualism, and Masculinity/Femininity*. Other studies, for example, Bochner & Hesketh (1994) and Stull & Von Till (1994) have used an instrument approach based on Hofstede's dimensions to study culture in education settings. Similarly, this study utilises an instrument containing scales whose construction were influenced these four dimensions.

An instrument, provisionally identified as the *Cultural Learning Environment Questionnaire (CLEQ)*, was developed specifically for use in this study. The initial development of *CLEQ* was guided by the following criteria:

i. Consistency with previous learning environment research. All relevant scales contained in relevant existing instruments for learning were examined for guidance in identifying the scales.

ii. Consistency with the social psychology, organisation sociology and anthropological literature.

iii. Consistency with management theory literature. Important dimensions in the unique environment of multicultural, multinational organisations were identified through an extensive review of the literature (Hofstede, 1984).

iv. Coverage of Moos' general dimensions. Scales for the *CLEQ* were chosen to include at least one scale from each of Moos' three dimensions.

v. Salience to teachers and students. By interviewing teachers and students an attempt was made to ensure that the *CLEQ's* scales and individual items were considered salient by teachers and students.

vi. Economy. *CLEQ* was designed to have a relatively small number of reliable scales, each containing a small number of items.

The result was a questionnaire containing eight scales: Role Differentiation, Collaboration, Risk Involvement, Competition, Teacher Authority, Modelling, Congruence, and Communication. A description of each of these scales, together with a sample item from each is provided in Table 1.

Table 1

Descriptive information for each scale in the CLEQ instrument

Scales	Description	Sample Item
Role Differentiation	Measures the extent to which gender roles are perceived to be differentiated or overlapped by students.	I feel that comments in class by male and female students are equally important (+)
Collaboration	Measures the extent to which students are part of a strong cohesive group.	I feel that it is important for the class to work together as a team (+)
Risk Involvement	Measures the extent to which students feel they can give their own opinion in class discussions.	I try to say what I think the teacher wants rather than give my own opinions (+)
Competition	Measures the extent to which the students that they are competitive with other students	I like to compete against the other students (+)
Teacher Authority	Measures the extent to which students feel they can challenge their teacher.	It is OK for me to disagree with teachers (+)
Modelling	Measures the extent to which the students prefer to learn by a process of modelling.	I like teachers to show me what to do (+)
Congruence	Measures the extent to which the students feel learning at school matches their learning at home.	What I learn in this class helps me at home (+)
Communication	Measures the extent to which students have more direct forms of communication with the person they are interacting with	I like to be able to see as well as hear what is happening in class (+)

Teacher-Student Interpersonal Behaviour

International research efforts involving the conceptualisation, assessment and investigation of perceptions of psychosocial aspects of the classroom environment have firmly established classroom environment as a thriving field of study (see reviews by Fraser, 1994; Fraser & Walberg, 1991). A team of researchers in The Netherlands extended this research by focusing specifically on the interpersonal relationships between teachers and their students as assessed by the *Questionnaire on Teacher Interaction (QTI)* (Wubbels, Créton & Hooymayers, 1985). The Dutch researchers investigated teacher behaviour in classrooms from a systems perspective, adapting a theory on communication processes developed by Watzlawick, Beavin and Jackson (1967). Within the systems perspective on communication, it is assumed that the behaviours of participants influence each other mutually. The behaviour of the teacher is influenced by the behaviour of the students and in turn influences student behaviour. Circular communication processes develop which not only consist of behaviour, but determine behaviour as well.

With the systems perspective in mind, Wubbels, Creton and Hooymayers (1985) developed a model to map interpersonal teacher behaviour extrapolated from the work of Leary (1957). In the adaptation of the Leary model, teacher behaviour is mapped with a Proximity dimension (Cooperation, C - Opposition, O) and an Influence dimension (Dominance, D, - Submission, S) to form eight sectors, each describing different behaviour aspects: Leadership, Helping/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. Figure 1 displays typical behaviours for each sector. The Questionnaire on Teacher Interaction (QTI) is based on this model.

Examples of items are "This teacher is friendly" (Helping/Friendly) and "This teacher gets angry unexpectedly" (Admonishing). The scores for each item within the same sector are added to obtain a total scale score. The higher the scale score, the more a teacher shows behaviours from that sector. Scale scores can be obtained for individual students, or can be combined to form the mean of all students in a class. An economical short 48-item version of the QTI was developed in Australia and containing six items for each sector of the model depicted in Figure 1.

The QTI has been shown to be a valid and reliable instrument (Wubbels & Levy, 1993). For example, the Australian version of the QTI was used with a sample of 792 grade 11 students and their 46 teachers, and the Cronbach alpha coefficients for QTI scales ranged from 0.80 to 0.95 for students and from 0.60 to 0.82 for teachers (Fisher, D., Henderson, D., & Fraser, B., 1995). This indicates that each QTI scale displays satisfactory internal consistency for scales containing only six items each. As with other classroom environment questionnaires, the QTI can be used in a preferred form where students respond in terms of what ideally they would prefer their class to be like rather than what it is actually like. The preferred or ideal form of the QTI was used in this study.

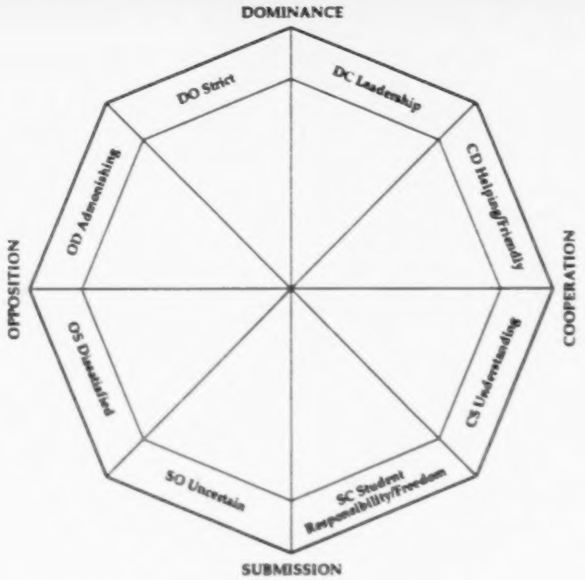

Figure 1. The model for interpersonal teacher behaviour

Methodology

The study reported here, is concerned with the culturally sensitive learning environments of secondary school students and how the cultural and contextual factors interact with what students would prefer the teacher-student interactions to be. The underlying premise of this research is that if we can identify the culturally sensitive learning environments of multicultural students in a given classroom then it follows that we have an opportunity to optimise the teaching strategies to be utilised with them. Specifically, the research seeks to determine students' culturally sensitive learning environments; students' preferred student-teacher interpersonal behaviours and then examine the relationship between students' culturally sensitive learning environments, and their preferred student-teacher interpersonal behaviours. Therefore, the two research tasks were to: develop the CLEQ and determine its reliability and validity; and investigate any differences between students' culturally sensitive learning environments, their attitudes and enquiry skills. This paper only reports the development and validation of the CLEQ

The study involved a survey of 1834 science students in 95 classes in 34 secondary schools. The CLEQ contained 40 items which had been construct and content validated by teachers, students and fellow researchers. Each scale contained five items. Each item was responded to on a five-point scale with the extreme alternatives of Disagree - Agree. Table 1 clarified the meanings of each of the eight scales by providing a scale description and a sample item. Students were asked to indicate to what extent they preferred the stated description.

Table 2.

Factor loadings for items in 40-item version of personal form for the individual student as the unit of analysis

Scale	Item No	Role Differentiation	Collaboration	Teacher Authority	Competition	Risk Involvement	Modelling	Congruence	Communication
Role Differentiation	1.	.74							
	2.	.74							
	3.	.62							
	4.	.75							
	5.	.63	.33						
Collaboration	6.		.80						
	7.		.73						
	8.		.71						
	9.	.35	.49						
	10.		.80						
Teacher Authority	11.			.71					
	12.		.31	.45					
	13.			.74					
	14.			.59					
	15.			.50	.44				
Competition	16.				.77				
	17.				.81				
	18.				.68				
	19.				.76				
	20.				.78				
Risk Involvement	21.					.71			
	22.					.81			
	23.					.77			
	24.					.59			
	25.					.66			
Modelling	26.						.68		
	27.						.72		
	28.		.31				.55		
	29.						.61		
	30.						.57		
Congruence	31.							.70	
	32.	.33						.67	
	33.							.78	
	34.							.72	
	35.							.74	
Communication	36.								.71
	37.								.64
	38.								.78
	39.								.71
	40.	.42							45
% Variance		17.6	7.0	3.1	11.2	4.0	3.2	6.6	5.1
Eigenvalue		7.0	2.8	1.2	4.5	1.6	1.3	2.7	2.0

Factor Loadings smaller than 0.3 have been omitted.

Results

Factor Analyses

The first stage in the refinement and validation of the preferred form of the CLEQ involved a series of factor analyses the purpose of which was to examine the internal structure of the set of 40 items. Using

SPSS, principal components analysis with varimax rotation was used to generate orthogonal factors. Since the instrument was designed with eight scales, a eight-factor solution was considered.

Table 2 shows the factor loadings obtained for 1,834 school students in 95 classes in 34 schools. The results in Table 2 were obtained using the individual student as the unit of analysis. The percentage variance extracted and eigenvalue associated with each factor also are recorded at the bottom of each scale. The only factor loadings included in this table are those greater than or equal to the conventionally accepted value of 0.30. Factor analyses supported the 40-item 8-scale version of CLEQ.

Instrument Reliability

The first research question explored involved the reliability and validity of the CLEQ instrument. The CLEQ data were subjected to item analysis and the internal consistency/reliability (Cronbach alpha reliability coefficient) and discriminant validity (mean correlation with other scales) are shown in Table 3. The table shows that for the sample of students the alpha coefficients ranged from 0.67 to 0.85. The reliability data suggest that each CLEQ scale has acceptable reliability, especially for scales containing a relatively small number of items. The mean correlation of a scale with other scales was used as a convenient measure of the discriminant validity of the CLEQ. The mean correlations ranged from 0.08 to 0.22 indicating that the CLEQ measures distinct (although somewhat overlapping) aspects of the cultural learning environment. The conceptual distinctions among the scales are justified by the factor analysis and discriminant validity.

Table 3.

Mean, item mean, cronbach alpha reliability and discriminant validity (mean correlation with other scales) for each scale of the CLEQ.

Scale	No of Items	Alpha Reliability	Mean Correlation with Other Scales	Scale Item Mean	ANOVA Results Eta^2
Role Differentiation	5	.81	.14	3.56	.12
Collaboration	5	.82	.14	3.12	.08
Risk Involvement	5	.67	.08	2.00	.10
Competition	5	.85	.16	2.04	.15
Teacher Authority	5	.76	.17	2.00	.12
Modelling	5	.69	.15	2.08	.09
Congruence	5	.82	.22	2.44	.12
Communication	5	.79	.22	2.72	.13

Although it was felt that detailed examination of the class as a unit of analysis was generally not meaningful, the possibility that the CLEQ was capable of differentiating between the perceptions of students in different classrooms was investigated. That is, does the mean within-class perceptions vary from classroom to classroom? This characteristic was explored for each scale with the 1,834 students in 95 secondary classrooms using one-way ANOVA, with class membership as the main effect and using the individual student as the unit of analysis. The results of these analyses reported in Table 3 indicate that each scale differentiated significantly (*$p<0.001$*) between classrooms. The eta^2 statistic, represents the amount of variance in the learning environment scores accounted for by class membership, ranged from 0.08 to 0.15.

Outcomes

Past environment research has often investigated associations between student outcomes and the nature of the classroom environment (Fraser, 1994). In order to permit examination of the predictive validity (i.e., the ability to predict student outcomes) of the perceived version of CLEQ, students completed a simple Likert-type questionnaire which assessed students' attitude towards science. Simple correlational analyses were used in examining the degree of association between students' perceptions of a culturally sensitive learning environment and attitudes. Overall, the dimensions of CLEQ were found to be related to students' attitudes. In particular, more favourable student attitudes were found with students who perceived less Role Differentiation ($p<0.01$), Collaboration ($p<0.01$), Teacher Authority ($p<0.05$), Competition ($p<0.01$), Risk Involvement ($p<0.01$), Congruence ($p<0.01$), and Communication ($p<0.01$).

Table 4

Student outcomes - simple and multiple correlation between attitudes and cleq scales

CLEQ Scale	Simple Correlation(r)	Standardised Regression Weight (,)
Role Differentiation	0.26*	0.12*
Collaboration	0.10*	0.64
Teacher Authority	0.06**	0.69
Competition	0.18*	0.13*
Risk Invovlement	-0.11*	-0.12*
Modelling	-0.02	-0.13*
Congruence	0.30*	0.18*
Communication	0.33*	0.20*
Multiple Correlation, R		0.43*
Sample Size	1834	1834

* $p<0.01$ ** $p<0.05$

These associations were further investigated using multiple regression. The multiple regression results were obtained when the whole set of eight learning environment predictors was separately regressed on attitudes and enquiry skills. Beta weights and significance levels from t tests are reported. Table 4 also includes the simple coreelation (r) between the attitudinal outcome and the input variables and the standardised regression coefficient (b) for each CLEQ scale. The magnitude and statistical significance of the regression coefficient provides a measure of the association between the outcomes and input variable when scores on the other input variables are held constant. It should be noted that there was a high degree of congruence between the results of simple correlation and multiple regression analyses.

Discussion

This article has described the development and validation of a questionnaire, (*CLEQ*) which assesses eight scales of the culturally sensitive learning environments of secondary school students. This exploratory study examined, in multicultural classrooms, relationships between secondary science students' perceptions of their attitudes towards science and their perceived culturally sensitive learning environments. Some might question how we can translate the results of such research into practical teaching strategies which are sensitive to the great diversity of preferred student culturally sensitive learning environments. However, the underlying premise of this research is that if we can identify the culturally sensitive learning environments of our secondary students in a given classroom then it follows that we have an opportunity to optimise the teaching strategies to be aligned with these cultural dimensions. It must not be assumed that we are arguing that only these preferred interactions must be utilized but rather teachers need to consider how different learning conditions are utilised given students' preferences for learning environments. This however poses a fundamental problem. What can the teacher do to utilise this important new information given the limited time available to teach a possibly already well defined syllabus?

First, the teacher can utilise this new information to better match the teaching strategies they select for that class with the preferred learning environments of their students. In practice, this would mean that the teacher, acting in the role of a secondary school-based curriculum developer, can select a balanced set of strategies and instructional approaches appropriate to the profile that has been determined by actual class measurement. It is assumed that these alternative approaches would be readily available to the teacher.

Second, in an era of democratic classroom decision-making, a number of important implications concerning student involvement in the learning process need to be noted:

- The students may be given more opportunity to choose the approach that best suits their individual interests and needs. That is, the teacher offers students alternative learning pathways in the form of a number of flexible learning approaches.
- The student is then able to choose the approach and format that meets their personal preference. Especially in those courses which have multiple groups, each group can utilise a learning approach that is more applicable to the many varied preferred learning styles of the subgroups. For example, one group may focus on a highly structured approach while another group may utilise constructivist approaches to learning.
- This approach that utilises a mix of different methods, not only negates some of the constraints that affect the selection of learning activities, but also provides the possibility of optimising the secondary school students' learning capabilities by the provision of a more culturally acceptable teaching approach.
- This information can provide the teacher about the appropriate mix of lecturing and tutorial methods that should be utilised throughout the course.
- In an era of multi-media and flexible approaches to learning, this may well be one way in which we can design more effective classroom environments for our students.

Finally,

> Recognition of the existence preferred learning styles leads to a notion of extending choice of learning method to the learner. The introduction of a modular approach to course organization opens up the possibility of extending choice of content to the learner (Hodson, 1993, p695).

Teachers can utilize this new information to better match the teaching strategies they select for that class with the cultural expectations of their students. In practice, this would mean that the teacher, acting in the role of a school-based manager of learning, can select a balanced set of strategies and instructional approaches appropriate to the profile that has been determined by the teacher.

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